Jigs and Fixtures

BOOKS

by

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JIGS AND FIXTURES

A REFERENCE BOOK

SHOWING MANY TYPES OF JIGS AND FIXTURES IN ACTUAL USE, AND SUGGESTIONS FOR VARIOUS CASES

By FRED H. COLVIN

Editor Emeritus of American Machinist; Author of "American Machinists' Handbook"; Fellow, American Society of Mechanical Engineer; Member, Franklin Institute

and LUCIAN L. HAAS

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PREFACE TO THE FIFTH EDITION

The rehabilitation of devasted countries and the need to rebuild our productive capacity to supply our own needs make economical production through the use of fixtures more necessary than ever. The increased cost of labor makes efficient jigs and fixtures essential in order to keep manufacturing costs low enough to maintain prices within the reach of the average buyer. This can be done only by utilizing the best in both machines and fixtures, plus efficiency on the part of both management and labor.

In this edition much of the material has been rearranged in order to make the information more easily available. There are also such new data as the new standards for drill jig bushings, on airplane assembly fixtures, on special fixtures for welding for mass production, and on special fixtures for use in railway shops.

Efficiency in fixture design has an important bearing on the cost of the product as well as of the fixture itself. Fixtures must be strong enough to resist distortion, which produces inaccuracies in the product, and yet as light as possible both on account of cost and of handling while in use. A careful study of the various suggestions for fixtures of different kinds as well as the principles involved will help in securing fixtures that are economical both in first cost and in production.

THE AUTHORS

NEW YORK, N. Y.
September, 1948

PREFACE TO THE FIRST EDITION

In these days of modern manufacturing, jigs and fixtures have become necessary both for interchangeability and reduced costs. And, while every tool designer is confronted by different problems, there are certain fundamental principles which can be modified to meet existing conditions and applied to most cases.

Bearing this in mind, we have endeavored to show these principles, as nearly in the order of their application as possible, so that the designer can select such parts and methods as seem best suited to his particular problem. While we have not by any means exhausted all the known devices used in jig work, we have endeavored to show enough to enable a suitable choice to be made and to suggest other methods should these not meet all requirements.

THE AUTHORS

September, 1913

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railroad shops which have a stable class of work not liable to rapid obsolescence. The general practice seems to be about two years, but conditions even within one shop might warrant lengthening or shortening this period for different specific cases.

SOME PRINCIPLES RELATING TO DETAILS OF DESIGN

Feeds.—The pressure due to the feed and rotation of the cutter should be against the solid part of the fixture, not against the clamp. This principle is often violated, as the wrong way is often more convenient. Figure 1 shows the older method of feeding against the rotation of the cutter, which is still used in many places. This is now called "out" or "up" feeding, preferably the former, because the cutting edge is leaving the surface of the work. The other method, first known as "climb" cutting and now as "in" or "down" cutting, gives better results where it can be used. In either case the cutter should tend to force the work against the solid part of the fixture, not against the clamp. The "in" feed gives the cutter a better bite on the work as it starts to cut.

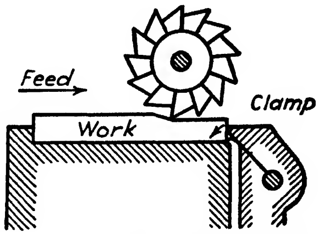


FIG. 1.—Pressure of cut should always be against solid part of fixture.

Locate the feed and cuts to throw the burrs for the various cuts on the same side, to reduce burring operations as far as possible. In order to be sure that burrs do not vitiate correct setting in subsequent operations, it is wise to provide clearance grooves on locating surfaces so that burrs cannot, even if left on, interfere with correct setting.

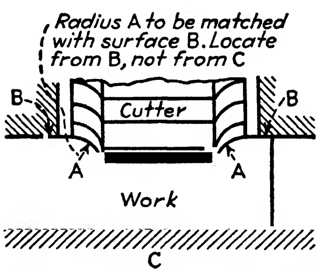


FIG. 2.—Locate work from the surface to be matched.

Locating.—Locating surfaces should be as small as is consistent with proper support and wear. The larger the surface the more care and time are necessary to keep it clean and free from chips which destroy proper setting.

If a surface is to be matched in a milling operation, locate from *that* surface as at *B* (Fig. 2). It may be more convenient to locate from the opposite face, but locating from the matching surface is correct and produces better work. A variation in the thickness of even a half of a thousandth will show, although it may not affect the operation of the piece.

Avoid sharp corners between locating surfaces. They catch dust and dirt and are hard to clean (Fig. 3).

The number of fixed supports should not be more than three. These should be as far apart as possible. If other supports are needed, they

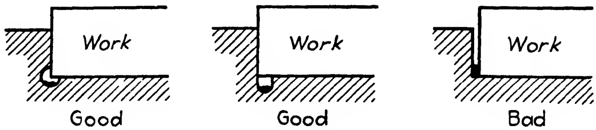


FIG. 3.—Provide space for dirt to secure proper location of work.

should have only spring tension against the work during clamping and be locked in position after the work is set.

It should be easy to keep the locating surfaces clean; therefore, there should be ample clearance for chips. If possible, accumulated chips

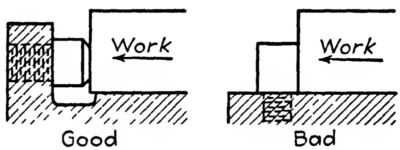


FIG. 4.—Buttons make better locating points than flat surfaces.

should fall away from, rather than on to, the locating surfaces when the work is removed. If possible, keep the locating surfaces completely covered by the work, so that chips cannot collect on them.

All the locating surfaces of a jig or fixture should be fixed. Movable surfaces should be used for clamping only.

Buttons or pins, hardened and ground, are often better for locating than flat surfaces, as they are easier to keep clean and afford easier adjustment for wear. They are better when acting endwise than sidewise, as there is no bending action and they are more readily set up for wear (Fig. 4).

It is better to support castings on buttons or pins than on flat surfaces. They position better and more definitely. Surfaces which locate drop forgings should have clearance for the flash and preferably should be located from one side of the flash only, as the dies which made the forging may not have been exactly matched. Locating from the upper side of the forging, or that above the flash, is preferable.

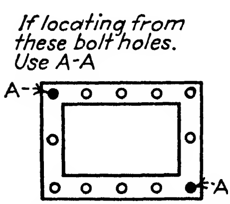


FIG. 5.—Locating holes and supporting points should be spaced as far apart as possible.

The clamping should not produce any horizontal sliding action across the locating faces, as this causes wear.

Locating and supporting points should be as far apart as the nature of the work will allow (Fig. 5).

The locating and support points should be visible and easily accessible to the operator.

Do not stack pieces one against another, if accuracy is required. In multiple work each piece should be located independently against fixed stops. In well-designed fixtures this is done, although several pieces may be clamped by one motion.

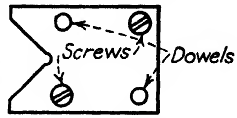


Fig. 6.—Depend on dowels for location, not on screws.

In multiple milling fixtures do not mill the pieces serially, with a single cutter, if the runs are long. Use multiple cutters, one for each piece, and feed across the row. This reduces the length of feed and therefore the cutting time. This applies, of course, to fixtures with a reciprocating feed, not to those with rotary, continuous feeds.

Parts of the fixture requiring accurate location should be held by screws and dowels or splines. The screws should not have to perform the double function of locating and holding (Fig. 6).

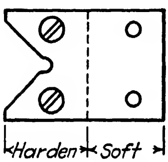


Fig. 7. Harden only contact portion of locating member.

When locating blocks are assembled into fixtures it is sometimes desirable to arrange the screws and dowels as shown in Fig. 7. When arranged this way, the contacting surface only is hardened, leaving the section carrying the dowel pins soft, so that the reaming of the holes and the alignment of the piece can be done after hardening.

Where the positioning need be only in one direction, the side of the piece or preferably a tongue and groove may be used for locating, and the screws go through slotted holes (Fig. 8).

If position pins are used for locating a previously drilled hole, that portion which is full diameter should be as short as is consistent with wear, and the rest or upper part of the pin tapering (Fig. 9).

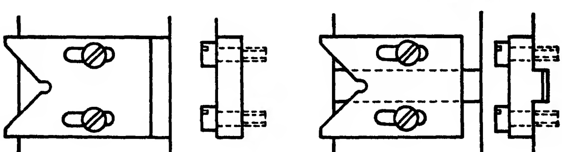


Fig. 8.—Sliding V blocks are often very convenient.

Locating pins should be hardened and ground with clearance for burrs and chips. When used with counterbored holes they should center on only one diameter.

When two pins are used for locating, one should be flattened, on the sides toward and away from the other pin (Fig. 10). Sometimes it is

desirable to flatten both pins, the plane of the flattening being at 90 deg., as shown in the lower figure.

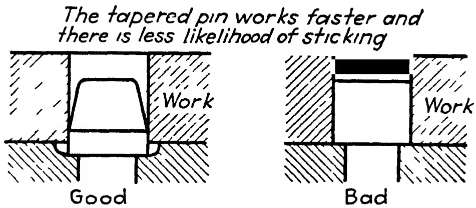


FIG. 9.—Tapered ends on locating pins save time.

If one pin is higher than the other, preferably the larger one, the work can be seated more rapidly.

Clamping.—Under no circumstances should the line of clamping pressure be outside the stop. If it did, there would be a tendency to lift the work. Side clamps should press downward as well as inward (see Fig. 1). By so doing the clamping tends to seat the work.

The clamp should be immediately opposite the supporting point, with solid metal between. Disregard of this leads to springing the work, or lifting of the work due to the support acting as a fulcrum (Fig. 11).

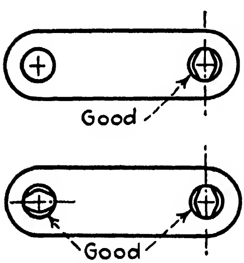


FIG. 10.—Locating pins can often be flattened to advantage.

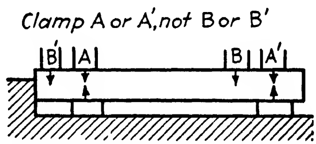


FIG. 11.—Clamp work directly over supporting points.

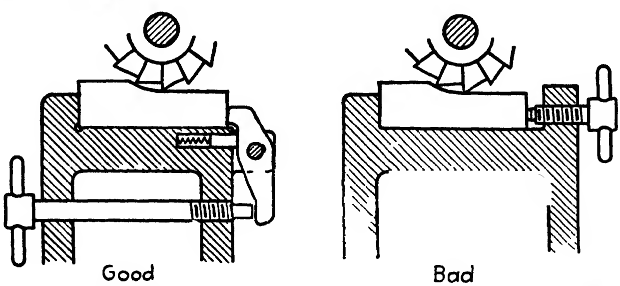


FIG. 12.—Clamps should always operate from the front of the fixture.

Clamps and adjusting points should be operated from the front or working side of the fixture (Fig. 12).

The tool thrust should be taken up by an adequate, fixed stop, not by the friction between the work and the clamp. Clamping jaws should, if possible, be at right angles to the direction of the cut, not parallel to it.

All the clamping strain should be cared for within the fixture itself. None of it should be transmitted to the table of the machine.

Cams or wedges, if used for clamping, should be so designed that the pressure and feed tend to tighten them, not to loosen them.

Clamps should have springs and washers under them so that the operator will not have to hold them back while inserting the work (Fig. 13). A better form, with the spring concealed so that chips cannot interfere with it, is shown in Fig. 14.

To save time in loading and unloading a fixture, clamps which have considerable motion should, in order to clear the work, have a rapid

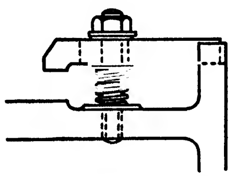


Fig. 13.—Springs under clamps save time and patience.

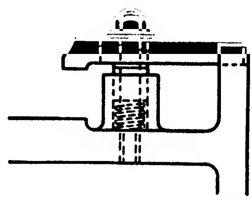


Fig. 14.—Concealed springs avoid trouble from dirt.

action when free from the work and a slow motion with increased power when they are brought into contact with it. A variety of devices are available, such as the toggle joint, bayonet screw, interrupted thread, slotted clamp, etc.

Clamps holding castings and irregularly shaped surfaces should be on the floating principle to enable them to adapt themselves to the shape of the work.

Jig Legs.—The center of gravity of the jig, with the work in it, and also the thrust of the drill should lie within the geometrical figure formed by the supports. This avoids a tendency for the jig to lift or tip.

A drill jig should have *four* legs. With a three-legged support it will rest stable on any surface. If a chip is under one leg of a three-legged support, the fact will not be detected. With a four-legged support the jig will teeter if it is on an uneven surface or a chip is under one of the supports.

Supporting strips or lugs are sometimes better than legs, as they are less likely to drop into T slots or holes in the machine table.

Jig Bushings.—Loose or screwed-in solid bushings should not be used where accuracy is important. Where screwed-in bushings are necessary they should center on cylindrical surfaces, not on the threads.

The length of bearing for the drill should, in fixed bushings, be about one and one-half to two times the diameter of the drill; in slip bushings, about two or three times the diameter of the drill. If the bushing is longer than this, the remainder of the length farthest from the work may be relieved.

Bushings should not be located close to the work with the object of carrying the chips up through the bushing except when the holes to be drilled are in a machined face which is clamped against a similar face in the jig. It is better, when the design will permit, to allow the chips to clear between the work and the bushing. About one drill diameter is

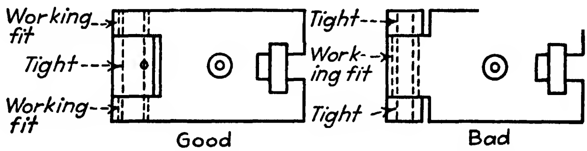


FIG. 15.—Latches should have good bearings.

usually sufficient. For small holes where great accuracy is required the bushing should be brought down close to the work. For drills smaller than No. 31 this dimension may be approximately $\frac{1}{64}$ in. with drills ground with a flat point.

Jig Latches.—In the joint of a latch give the latch the widest possible hold on the hinge pin (Fig. 15).

A still better type of latch is shown in Fig. 16, which gives better side support when in working position. If possible, avoid placing clamps

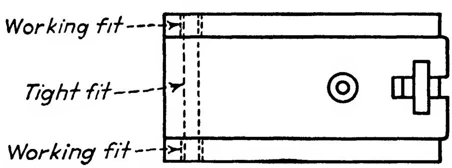


FIG. 16.—A good design of latch hinge, or bearing.

in a latch which carries drill bushings, as any clamping pressure has a tendency to spring the latch and throw the bushings out of alignment.

Preferably a jig latch should have a support or stop to hold it when it is thrown back. This lessens the possibility of misalignment through use.

It may be of advantage to have the hinge pin tapered. This permits readier adjustment for wear, etc.

General.—Thumb nuts, fluted nuts, and levers should be used where the quantities are large, as the necessity of handling wrenches is thus avoided. They should be large enough to give the required pressure

easily. When it becomes necessary for an operator to use a mallet, time is lost, and either the work or the fixture is likely to be sprung.

Thumb nuts and hand knobs should have ample clearance around them to permit their being manipulated properly and to avoid possibility of injury. Avoid knurling nuts and handles. When covered with cutting lubricant they are irritating to the operator's hands under constant use.

If it is necessary to use a wrench in setting the work, the various nuts should preferably be of the same size, so that change of wrenches is not necessary.

All exposed screws, nuts, and lugs, the motion of which might catch the operator, are to be avoided, and all sharp corners and edges should be removed.

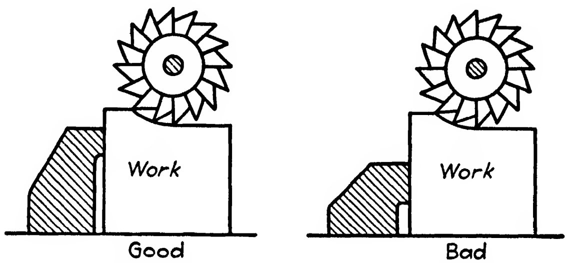


FIG. 17.—Work should be supported as near the tool thrust as possible.

The operator's hands must be well clear of the cutters during the insertion, clamping, and removal of the work.

There should be no danger of destruction of the work, tool, fixture, or machine through the overrunning of the cutter.

It is desirable to have the cutting zone as close to the machine table as possible. If for some good reason it must be high, then the surface taking the thrust of the cut should be high, *i.e.*, as nearly in line with the cut as possible (Fig. 17).

It is desirable that parts subject to wear be renewable without destroying the jig or fixture.

JIG DESIGN

Those interested in the designing of jigs can find many points for consideration in the problem given by the American Machinery & Tool Institute. The illustration (Fig. 18) shows both the part to be drilled and the jig that was awarded the prize. The piece of duralumin is drilled from five of its six sides, so that feet have had to be provided on all but one side.

Eleven points were considered in judging the merits of the jigs:

	Points
1. Adaptability to standardization	15
2. Pattern .	10
3. Design	10
4. Method of loading	10
5. Speed of clamping	10
6. Clearance	10
7. Ingenuity shown	10
8. Operations	10
9. Details	5
10. Loose parts	5
11. Miscellaneous and novelty	5

These may well be considered in all jig designing.

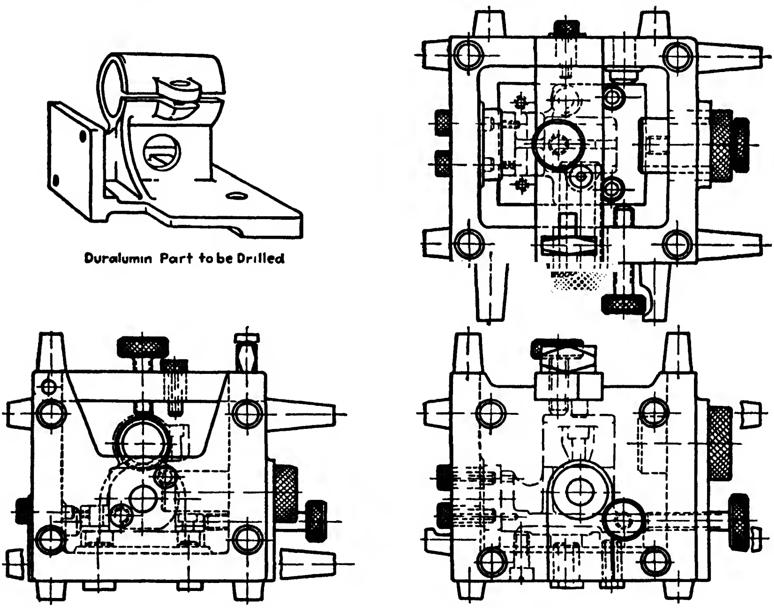


FIG. 18.—Prize-winning jig for drilling the part shown.

The design is for a cast-iron jig with feet and bushings located at the proper points. Whether or not it would have been advisable to make this jig by welding five plates into a box is a debatable problem. The operation of the jig can be easily seen by a little study, and it may suggest means of doing other somewhat similar jobs.

Section 1

STANDARDIZING FIXTURE DESIGN

CHAPTER I

DESIGNING JIGS AND FIXTURES

While the details of fixture design depend on several factors, such as cost, quantity of work, and the ingenuity of the designer, there are several suggestions that it is well to bear in mind. The following points to be considered are listed by the Taft-Peirce Mfg. Co. for guidance in making and checking tool drawings. There may be differences of opinion as to whether or not they are listed in the order of their importance. The points are:

Simplicity.

Rigidity of clamping devices.

Sequence of operations.

Interferences in the tool itself.

Interferences with the machine on which used.

Clearances for work and hands.

Avoidance of chip pockets.

Locating points should correspond with dimensions on part drawing and with locating points on other tools for the same part.

Convenience and speed in operation.

Accuracy of work produced.

Durability.

Economy of construction.

Stock sizes of material should be used.

In making the drawing it is necessary to consider the accuracy as to scale, the correctness of the projections, proper representation of the fixture and the work, and its blueprinting qualities.

The dimensions on the drawings must be accurate and must be put on by a method that will insure that there is enough without unnecessary repetition; that they are legible, that they contain the tolerances in understandable form, and that dimensions which are out of scale will be underlined to call attention to that fact.

Drawings must also contain information or specifications as to materials, finish marks, the kind of heat treatment if any, finish of

surfaces by grinding or otherwise, necessary notes, instructions for marking, part numbers and title of the part.

Where patterns are to be made there are four major considerations:

Economy of construction.

Ease of molding.

Equality of sections to avoid unequal shrinkage.

General appearance.

Wherever possible, stock patterns should be used.

OTHER POINTS FOR CONSIDERATION

Will the fixture be similar to some other that has been used to advantage? If so, can you improve upon it?

Has the part undergone any previous operations? If so, can you use any of these points to step from?

Is it absolutely necessary to work from any previously bored or finished surface?

Will a table of clamping schemes help you?

Can any stock castings be used for making the fixture?

Would it be of advantage to make a special pattern?

Can the part be quickly placed in the fixture?

Can the part be quickly removed from the fixture?

Is the part held firmly so that it cannot work loose, spring, or chatter while the cut is on?

Always bear in mind that the cut should be against the solid part of the fixture and not against the clamp.

Can more than one part be placed in the fixture and so increase the output?

Can the chips be readily removed from the face of the fixture upon which the part is located or clamped?

Are the clamps on the fixture strong enough to prevent them from buckling when they are tightened down on the work?

In using cams or wedges for binding or clamping the work, always bear in mind that through the vibration or chatter of the fixture or work they are apt to come loose and cause a great deal of damage.

Are there any special wrenches to be designed to go with the fixture?

Can you use a reversible key in the milling fixture, and will it fit the millers on which the fixture is to go?

Can a gage be designed, or hardened pins added, to help the operator set the milling cutters or check up the work?

Must special milling cutters, arbors, or collars be designed to go with the fixture?

Is there plenty of clearance for the arbor collars to pass over the work without striking?

If the fixture is of the rotary type, have you designed an accurate indexing arrangement?

Can the fixture be used on a standard rotary indexing head?

Is the fixture strong enough to prevent any vibration while the cutters are in action?

Can the fixture be made to take in more than one operation? If so, would it be advisable to have it do so, instead of making two fixtures?

Have you, in the designing of the fixture, brought the work as close to the table of the miller as possible?

Can the part be milled in a standard miller vise by making up a set of special jaws and thus doing away with an expensive fixture?

If the part is to be milled at an angle, could the fixture be simplified by using a standard adjustable milling angle?

Is there any danger of injury to the operator through the faulty design of the fixture?

Can lugs be cast on part to be machined to enable you to hold it?

What arrangements have you made to prevent the clamps from turning while they are being tightened on the work?

How many different-sized wrenches must the operator have in order to tighten all clamps? Why will one not do?

Can the work be gaged in the fixture, or must the fixture be cut away so that a micrometer, or snap gage, can be used?

Can you use jack pins to help support the work while it is being milled?

Will a reciprocating fixture be of advantage in getting out production?

Can a profile be used to help the operator in accurately locating the part?

Have you placed springs under all clamps?

In the building up of the fixture are all parts properly screwed and doweled in place? Is there any danger of their working loose?

Are all steel contact points, clamps, etc., hardened?

What kind or class of jigs are you going to design? Will any of the standard jig designs shown help you?

Has the part undergone any previous operation? If so, can you utilize any of these points to start from?

If locating against rough or unfinished surface, is it advisable to have locating points adjustable?

Can any of the clamping schemes shown be used to hold the part securely while it is being drilled and reamed?

Can any of the standard stock castings or patterns shown be used in making the jig, or must you make a special pattern?

Can the work be held down by any of the methods illustrated? If so, will the results after drilling and reaming be accurate enough?

What takes the thrust of the drill? Can you use any jack pins or screws to support the work while it is being drilled?

Can a drilling angle, as shown, be used to advantage to take care of a hole that is on an angle?

Can the standard wrenches and handles be used with the jig?

Are there any gages to be designed to help the operator get quick and accurate results from the jig?

Can you use a double or triple thread on the screw that holds the work in the jig, so that it will take fewer turns to get the screw out of the way in order to remove the part more quickly?

Are there any loose parts of the jig, such as clamps, that could be made integral with the jig and thus prevent their getting lost?

Have you made a note on the drawing, or have you stamped all loose parts with a symbol indicating the jig that they were made for so that in case they are lost or misplaced they can be returned to the jig when found?

Are all necessary corners rounded?

Is there any danger of the operator's being injured through the faulty design or make-up of the jig?

Can the toolmaker make the jig?

Are your drill bushings so long that it will be necessary to make up extension drills?

Are the legs on the jig long enough to allow the drill, reamer, or pilot of the reamer to pass through the part a reasonable distance without striking the table of the drill press?

Have you provided against clamps turning?

Are all clamps located in such a way as to resist or help resist the pressure of the drill?

Will a profile on the base of the jig help you to locate accurately the part to be drilled?

Have you provided springs under clamps or bushings?

Is the work apt to spring when tightening down on clamps?

If the jig is a rotary jig, is the indexing positive and accurate? Can you use a straight index pin instead of a tapered one?

If the part can be tapped or spot faced in the jig to advantage, have you provided large enough slip bushings?

Has the counterbore been provided with stop collars?

Has the drill press the necessary speeds for drilling and reaming all holes? Must it have a tapping attachment also?

Always remember that it is not practical to have several small holes and only one large one to be drilled and reamed in the same jig, for the reason that quicker results can be obtained by drilling the small holes on a small drill press, while, if there is only one large one, it would require the jig to be used on a large machine. The question then arises, Is it cheaper to drill the large hole in another jig, and will the result, after so drilling, be accurate enough?

Is the jig too heavy to handle?

ELEMENTS IN JIG AND FIXTURE DESIGN

The success or failure of jigs, fixtures, and miscellaneous tooling for machine tool applications depends on a complete analysis of all involved factors. To aid in making such an analysis, the Caterpillar Tractor Company suggests checking the following design elements:

Piece Part.

1. Study piece-part drawing.
2. Establish a mental picture of the part.
3. Relate this picture to the operation being considered.
4. Check the operation sequence.

The Machine.

1. Check the type and capacity of the machine to be used.
2. Check the possibilities and limitations of machine usage.

Production Requirement.

1. Determine the type of jig, fixture, or tool best suited to meet requirements.
2. Will available machine burden require manual semi-, or full-automatic, single or multiple setup?

Method of Location.

1. If first machining operation should be on castings or forgings, determine if location points have been provided to ensure equal distribution of metal on all subsequent operations. If not, plan location accordingly.
2. Determine points of relationship and maintain continuity throughout machining process.
3. Study possible arrangement of location points on the fixture to facilitate cleaning.
4. Is foolproofing required?

Handling.

1. If by hand, be sure part is within handling capacities.
2. If by hoist, check facilities and necessary sling clearance. Provide loading skids when necessary to ensure easy handling when sling is removed.
3. If by conveyer, check to maintain correct height.

Loading and Unloading.

1. Provide ample hand clearance.
2. Can reasonable balance be maintained to ensure safety?

Clamping.

1. Are loads static or shock?
2. Determine type of locking medium most suitable.
3. Arrange to maintain maximum rigidity without distortion.
4. Will action mar or injure part?

Thrust and Torque.

1. Can satisfactory blocking be arranged to withstand cutter feed strains and distortion.
2. Avoid clamps carrying thrust loads.

Chips.

1. Provide ample chip clearance and convenient means of removal.
2. Avoid blind spots and traps.

Capacities.

Will the proposed design come within the column-clearance capacity, table and spindle travel of machine?

Dry or Wet Job.

Is machine equipped for coolant? Can suitable coolant reservoirs be provided?

Tool.

1. Can the design be arranged to ensure use of standard tools (drills, reamers, milling cutters, etc.)?
2. Can use of existing special tools be incorporated?
3. Have provisions been made to secure all special tools needed?

Standard Parts.

Does the proposed design incorporate fully the use of all standard jig and fixture parts carried in stock?

Loose Pieces.

How can proper identification and storage be provided for all loose clamps, removable locating plugs, and adaptors?

Balance.

Have balance weights been figured and provided for on all trunnion and indexing fixtures to ensure safe operation?

Progressive Experience.

1. Does similar type of equipment exist? If so, what has been your experience with it?
2. Have machine-shop or toolroom suggestions been acted upon and incorporated?

Can It Be Built?

1. Does the proposed design include any impossible machining problems?
2. Does it conform to all known machine capacities?

Castings.

Does the design lend itself to good pattern-making practice and economical castings?

Welded Construction.

Would welded steel construction offer any advantages?

Material.

Have the proper steels been selected to make the miscellaneous details?

Safety.

1. Will finished tool be safe to operate?
2. Has any new accident hazard been created?
3. Can danger be eliminated?

Tool Records.

Has the tool-records file been carefully set up and adequately cross-filed for future reference?

POINTS TO BE CONSIDERED

Many items enter into the proper design of jigs and fixtures that are not apparent to the casual observer, according to J. A. Potter, chief tool designer of the Singer Mfg. Co. To him a finished jig or fixture may seem to be nothing more than rough castings or built-up pieces of steel with a few seats and straps to hold a part in place. The study of the operation writer to provide a proper sequence for machining, the care with which the tool designer laid out those straps to hold the work without springing it, and the accuracy with which the toolmaker set the seats and bored the holes do not show on the surface, but the real value can be easily determined when the tool is put into use.

It will be found that tool design is not a haphazard, hit-or-miss proposition. Each manufacturing concern must decide upon the

quality of work that it wishes to produce, and it must adopt certain standards of design and tolerance which will produce that quality. Medium-sized pieces are adapted to a variety of jig designs; the standards adopted will determine the style of fixture and the number of operations to be performed in each jig or fixture.

For instance, if a piece requires 14 operations of drilling, reaming, countersinking, and counterboring to be done in one jig, it can be handled in several ways. The operations can be performed on two eight-spindle gang drills or on three six-spindle machines or even on four, four-spindle machines by passing the jig from machine to machine and returning it to the original station on a conveyor. This, of course, requires several duplicate jigs and is one method for large production. The same jig can be used on any one of the machines by carrying out eight, six, or four operations, according to the number of spindles, and by finishing up with a change of tools in quick-acting chucks for the remaining operations. Either of these methods may be said to have a good point in that all operations are performed in a jig at one setting, all holes being necessarily in proper relation with each other, yet one method ties up machine tools, and the other wastes man hours.

If for the same part with 14 operations two or three jigs are made for the eight- or six-spindle machine, a more flexible arrangement results. It is possible to group the larger holes in one jig and the smaller in another, gaining time by the use of a faster speed for the small holes.

The size of the parts to be drilled will, of course, have a decided influence on the type of jig to be adopted. Large parts will usually be handled with the templet-and-stand type of jig, in preference to the box form. The usual run of templet design, however, is not a very interesting proposition, though considerable ingenuity is required to position and hold some templets in place. Exceedingly small parts with the corresponding small holes are often not drilled under the drill press at all but are fastened to a stem with a balance wheel and loaded into a specially devised steady rest on a speed, or watch, lathe. The tail end is then revolved in a direction opposite that of the chuck which holds the drill.

Standard drawing-room practice and symbols have been adopted by the American Society of Mechanical Engineers and

other societies and are now a standard of the American Standards Association. These standards are given herewith and should be used to avoid confusion.

AMERICAN STANDARD DRAWINGS AND DRAFTING-ROOM PRACTICE

Arrangement of Views.

Orthographic Projection.—For drawings in orthographic projection the third-angle system, known in Europe as "American projection," has been in practically universal use in the United States for many years and is continued as the American Standard. A brief discussion of this practice will be based on sketches of the object shown as Fig. 1.

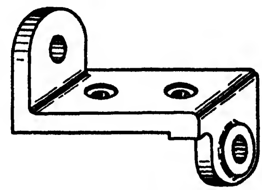


Fig. 1.—The basic sketch used.

In third-angle projection the top view is placed directly above the front view, the right-side view to the right of and facing the front view (Fig. 2), and, similarly, the left-side view to the left of the front view (Fig. 3).

When space limitations require, the side view may be placed across from the top view, as in Fig. 8. Figure 4 shows the relative positions of the six possible principal views of an object,

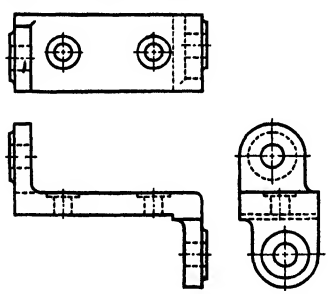


Fig. 2.—As it appears in third-angle projection.

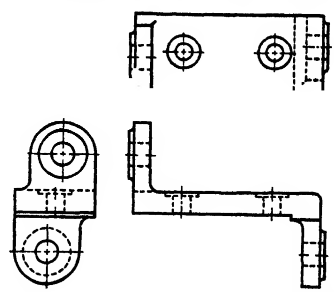


Fig. 3.—This shows the left-side view.

front, top, right side, left side, rear, and bottom. A bottom view, or "view looking up," can be used to advantage instead of a top view when the shapes or operations to be shown are on the underside of the part. For example: In a punch-and-die drawing the arrangement of views would be as in Fig. 6 with the view of the bottom of the punch placed in the position of the bottom

view; and the top of the die in the position of the top view, each facing the front view. In case of lack of space this arrangement is modified by placing the drawing of the bottom of the punch to the right of and in line with the top view of the die, as if it were turned over from the top view (Fig. 7). In drawings where any such arrangements of views are employed the views should always be carefully titled to aid in the reading.

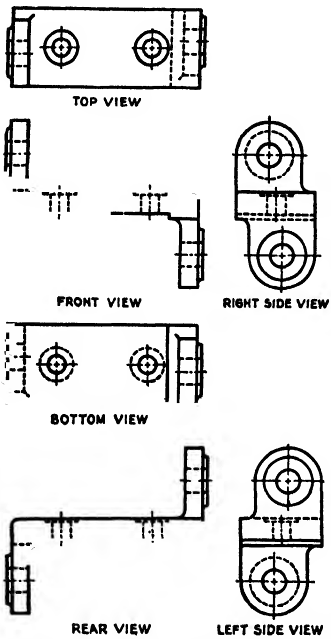


Fig. 4.—Relative positions of the six principal views.

For objects where two side views can be used to better advantage than one, these need not be complete views of the entire object, if together they describe the shape of the object (Fig. 5). Only those views should be drawn that are absolutely necessary to portray clearly the shape of a part. Often two views will suffice, and many cylindrical parts may be portrayed adequately by one view if the necessary dimensions are indicated as diameters (see Figs. 38 to 41).

Bottom views (views looking up) should not be used in steel-plate and structural drawings. Instead, the view should be shown as a sectional view looking down, the cutting plane passing a little above the bottom.

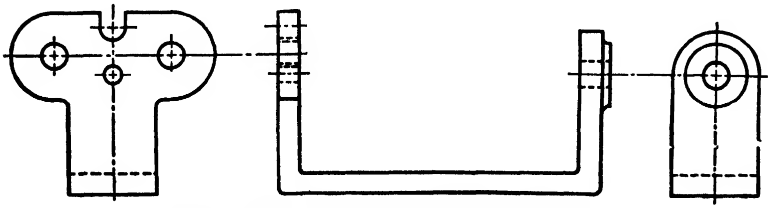


Fig. 5.—Where two side views are preferable.

As a general rule, a view should be made in each direction in which the contour of a characteristic shape necessary to the construction would be shown.

On exterior views hidden lines should be indicated, using the symbol for hidden lines shown in Fig. 9. This line should always begin with a dash in contact with the line from which it starts, except when the dash would form a continuation of a full line.

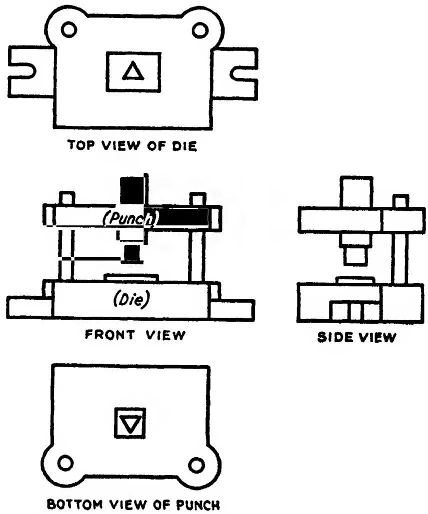


FIG. 6.—Normal arrangement of punch-and-die drawings.

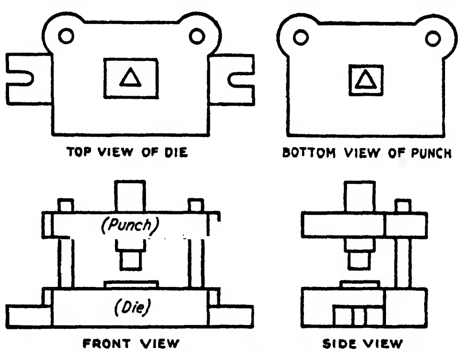


FIG. 7.—A modification that is sometimes used.

Dashes should touch at corners. Circle arcs should start with dashes at tangent points.

Lines and Line Work.

Line Characteristics.—It is recommended that the conventional line symbols shown in Fig. 9 be used on engineering drawings.

All lines should be clean and black, to permit of process reproduction of the drawing. As few hidden lines as practicable should be shown, sections being preferable in many cases. The actual width of each type of line should be governed by the size and style of the drawing, the relative widths of the lines to be approximately those shown in Fig. 9.

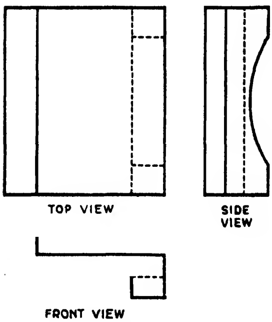


FIG. 8.—This may be used where space is limited.

Three weights of line, heavy, medium, and light, are shown and are considered desirable on finished drawings in ink, for both legibility and appearance, although in rapid practice and, in particular, on penciled drawings from which blueprints are to be made this may be simplified to two weights, medium and light. For pencil drawings the lines should be in proportion to the ink lines: "medium" for outlines

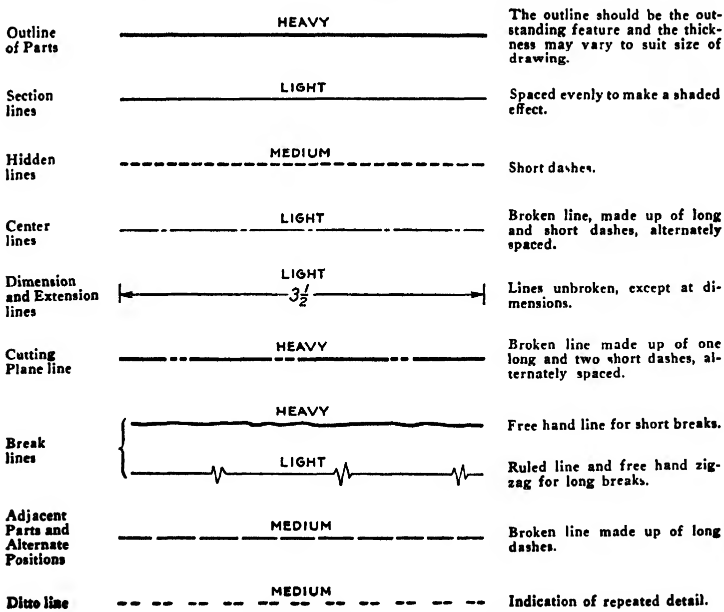


FIG. 9.—Conventional line symbols to be used.

and for hidden, cutting-plane, short-break, adjacent-part, and alternate-position lines; and "light" for section, center, extension, dimension, long-break, and ditto lines.

Dimension lines should be made as light lines, unbroken except for the space left for the dimension. Extension lines should be fine full lines of the same weight as dimension lines. They should not touch the outline of the object.

Break lines may be used on both detail and assembly drawings. On small parts heavy freehand lines are best, while on assemblies or large parts the second form, made with light ruled lines with freehand zigzags is preferred. The method of indicating the ends of shafts, rods, tubes, etc., that have a portion of the length broken out is shown as in Fig. 10.

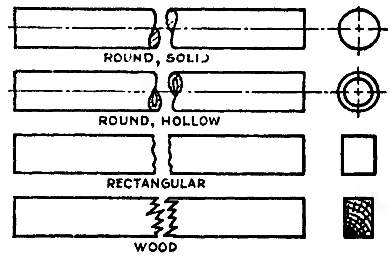


FIG. 10.—To show ends with pieces broken from the middle.

An alternate position, or indication of the limiting positions, of a moving part should be shown by a line made up of long dashes of medium weight (Fig. 11). Adjacent parts added on a drawing to indicate the position or use of the piece represented are drawn with the same symbol of long-dash lines (Fig. 12). This line is also used in showing

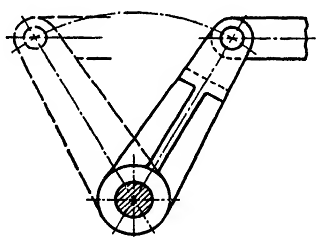


FIG. 11.—Showing alternate or limiting positions of a moving part.

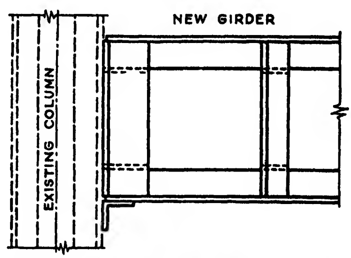


FIG. 12.—Showing position or use of adjacent parts.

machining bosses and lugs cast on for holding purposes, which are to be removed later.

General.—Sectional views, or "sections," should be used when the interior construction cannot be shown clearly by outside views. A sectional view should be made as if on that view the front part of the object were cut or broken away. The exposed cut surface of the material is indicated by "section lining" or "crosshatching" with uniformly spaced fine lines. Hidden lines and details

beyond the cutting plane should be omitted unless required for the necessary description of the object.

Symbolic section lining for the graphic indication of various materials of construction may be used when it is desired to call special attention to or to identify certain parts (see Fig. 13). If preferred, the section lining of any piece may be made by equally spaced full lines in one direction. In this case an opening is left in the sectioning to provide for a reference letter or word to indicate the material of which the part is made. Even when the symbolic types of section lining are employed, it will be found

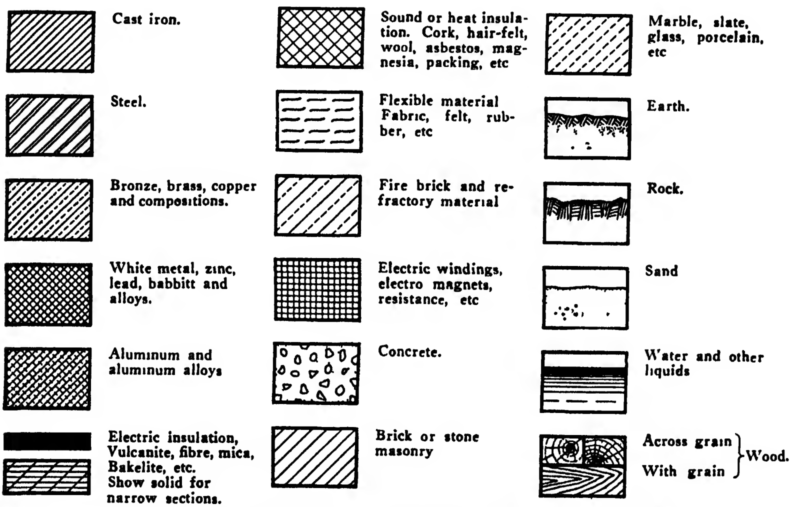


Fig. 13.—Standard section lining for different materials.

desirable frequently to use reference letters to indicate the heat treatment that the material is to receive.

Cutting Plane.—The cutting plane on which the section has been taken should be indicated by a heavy broken line consisting of one long and two short dashes alternately spaced and lettered at the ends, as *AA* (Fig. 14). Arrows are used to indicate the direction in which the section is viewed. On simple symmetrical objects the heavy line, letters, and arrows may be omitted. It is not necessary that the cutting plane be a single continuous plane; it may be bent or offset if by so doing the construction can be shown to better advantage, as, for example, *AA* or *BB* (Fig. 14). The reference letters should be repeated at points of change in

direction unless the changes are short and frequent. When the cutting plane extends entirely across the object, a "full section" is obtained. A symmetrical object may be drawn as a "half

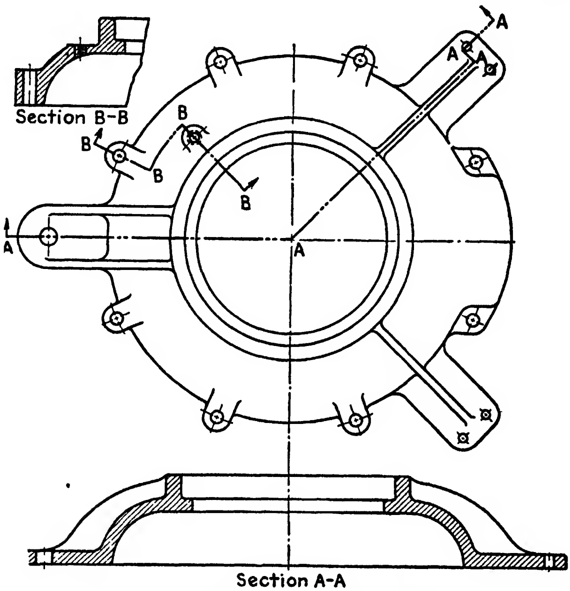


FIG. 14.—Showing different sections.

section," showing one half, up to the center line, in section and the other half in full (Fig. 15).

Revolved Sections.—These show the shape of the cross section on the longitudinal view of a part, such as the arm of a wheel, the cutting plane being rotated in place (Fig. 16). "Detail sections" should be drawn similarly except that they are placed to one side and often are made to larger scale than the view on which they are indicated (see Section *BB*, Fig. 14).

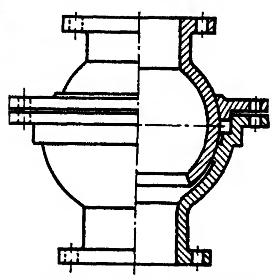


FIG. 15.—Symmetrical half section.

Other Types of Sections.—Broken-out sections should be used where a sectional view of only a portion of the object is needed (Fig. 17). Phantom, or dotted, sections are outside views with the interior construction shown by *dotted* crosshatchings. Their use sometimes saves the making of an extra view (Fig. 18).

Section Lining.—Section lining should be made with light parallel lines at an angle of 45 deg. with the border line of the drawing and spaced from $\frac{1}{32}$ to $\frac{1}{8}$ in. depending on the size of the drawing and of the part. Two adjacent parts should be sectioned in opposite directions. A third, adjacent to both, should be sectioned at 30 or 60 deg. If cut in more than one place, the sectioning of any part should be the same in direction and spacing. If the shape or position of the part would bring 45-deg. sectioning parallel or nearly parallel to one of the sides, another angle should be chosen.

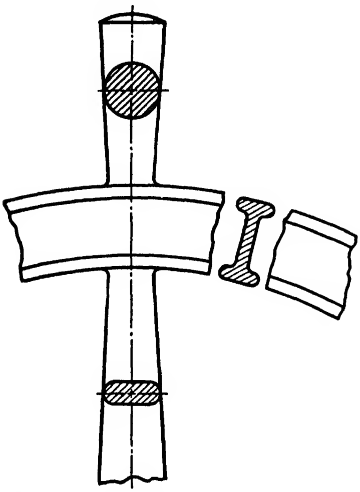


FIG. 16.—Sections may be revolved.

Thin Sections.—Sections that are too thin for line sectioning may be shown solid, for example, structural shapes, sheet metal, packing, or gaskets. Where two or more thicknesses are shown a white line should be left between them (Fig. 19).

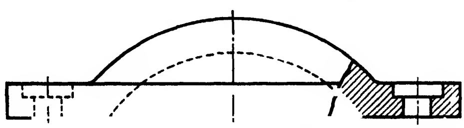


FIG 17.—Broken-out sections.

Exceptions.—There is one important violation of the conventional theory which is made in the interest of clearness. When

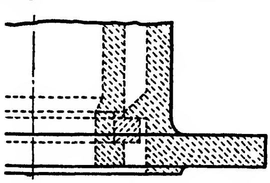


FIG. 18.—Phantom, or dotted, sections.

FIG. 19.—Solid lines for thin sections.

the section plane passes through a rib, web, or similar parallel element, section lines should be omitted from those parts (Figs.

14 and 20). Shafts, bolts, nuts, rods, rivets, keys, pins, and similar parts whose axes lie in the cutting plane should not be sectioned (Fig. 21).

When the true projection of a piece may be misleading, parts, such as ribs or arms, should be rotated until parallel to the plane of the section or projection. The representation in Figs. 14 and 22, for example, is preferred rather than the true projection.

Drilled flanges in elevation or section should show the holes at their true distance from the center rather than the true projection (Fig. 20).

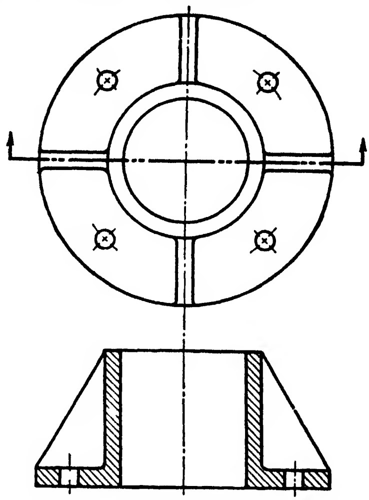


Fig. 20.—Omitting section lines.

Dimensioning.

General.—All drawings must be so dimensioned that the parts shown thereon can be made without the necessity of scaling the drawing. The dimensions should include those sizes and distances which are worked to in actual shop or constructional operations and should be so given that computations will not be necessary.

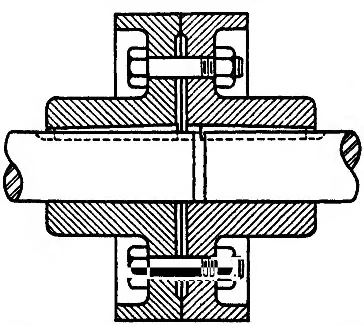


Fig. 21.—Parts that should not be sectioned.

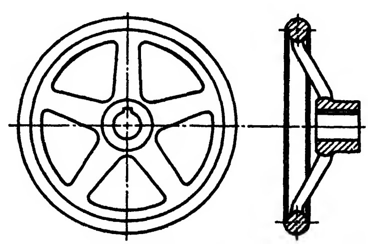


Fig. 22.—When true projection might be misleading.

Dimensions should not be duplicated on various views or a single view, except where they will add to the clarity of the drawing, and no more should be given than those required to produce the part.

Dimensions of parts that can be measured or that can be produced with sufficient accuracy by using an ordinary scale should be written in units and common fractions. Parts requiring greater accuracy should be dimensioned in decimal fractions.

Wire, tubing walls, sheet metal, standard structural sections, etc., should be described by commercial designation followed by dimension in decimals.

Dimensions up to and including 72 in. should preferably be expressed in inches; and those greater than this length, in feet and inches.

Where dimensions call for accurate machining with small tolerances, it is recommended that the total dimension be given in inches and decimal fractions.

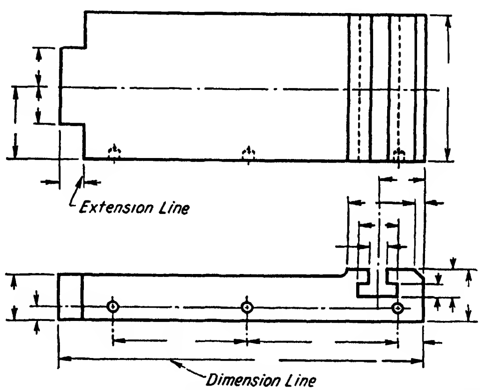


FIG. 23.—Dimension lines, extension lines, and leaders.

In structural drawing all dimensions of 12 in. and over should be expressed in feet and inches.

In automotive, locomotive, sheet-metal, and some other practices all dimensions are specified in inches.

The symbol (″) is used to indicate inches and common and decimal fractions of an inch.

When all dimensions are given in inches, the symbol is preferably omitted. A note may be placed on the drawing stating that all dimensions are given in inches.

The symbol (′) is used to indicate feet and fractions of a foot. Dimensions in feet and inches should be separated, thus 4′ 3″; 4′ 0½″; 4′ 0″.

Fractions should be written with the division line horizontal or in line with the dimension line (Fig. 25).

Dimension Lines, Extension Lines, and Leaders.—Dimension lines should be fine full lines (broken where dimension is inserted) so as to contrast with the heavier outline of the drawing, and should be placed outside the figure wherever possible (see Figs. 23 and 26).

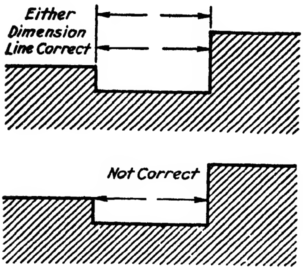


FIG 24.—Dimension lines.

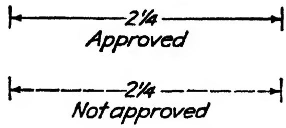


FIG. 25.—Dimension figures.

Dimension lines should be terminated by carefully made arrowheads whose lengths are approximately three times the spread. The distance from tip to tip of the arrowheads indicates the extent of the dimension.

Extension lines indicate the distance measured when the dimension is placed outside the figure. They are made as light full lines starting $\frac{1}{32}$ to $\frac{1}{16}$ in. away from the outline and extending about $\frac{1}{8}$ in. beyond the dimension line (see Figs. 23 and 26).

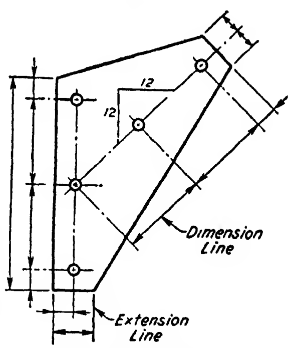


FIG. 26.—Leaders should be straight lines, not curved.

Leaders should be made up of light straight lines terminated by arrowheads. They should not be curved or made freehand (see Figs. 26 and 27).

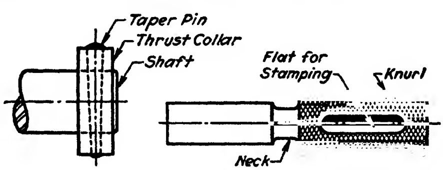


FIG. 27.—Angular lead lines.

A center line should never be used as a dimension line. A line of the piece or part illustrated or an extension of such a line should never be used as a dimension line (see Figs. 24 and 26).

Dimension Figures.—A dimension line must not pass through a dimension figure. If unbroken lines are used, as in common

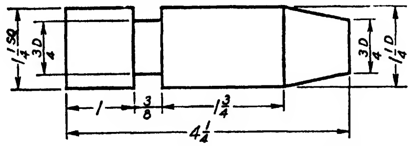


FIG. 28.—Approved method of dimensioning.

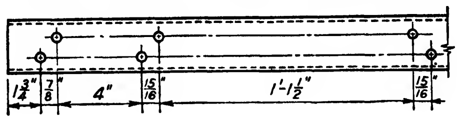


FIG. 29.—Dimension figures above solid line.

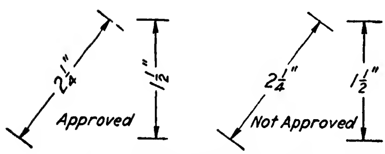


FIG. 30.—Dimensions should read either from bottom or from right-hand side.

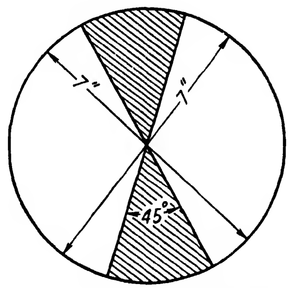


FIG. 31.—Avoiding confusion with shaded area.

practice in structural drawing, the dimensions are placed above the line Fig. 29. When fractional dimensions of less than one inch are given, the numerator should be placed above the dimension line, and the denominator below (Fig. 28).

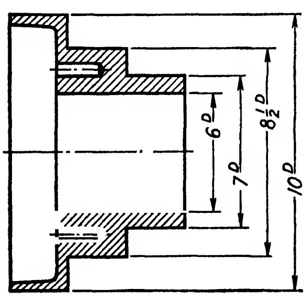


FIG. 32.—Staggering dimension figures.

All dimension lines and their corresponding numbers should be placed so that they may be read from the bottom or right-hand edges of the drawing (Fig. 30). All dimensions should be placed so as to read in the direction of the dimension lines, as shown in Fig. 30. Dimension lines should not be run in directions included in the shaded area shown in Fig. 31, 45 deg. from the vertical, unless unavoidable.

When there are several parallel dimension lines, the figures should be staggered to avoid confusion (Fig. 32).

Dimensions should be given from a base line, a center line, or a finished surface that can be readily established (Fig. 35).

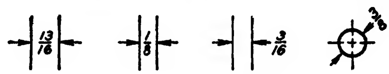


FIG. 33.—Using reverse arrowheads.

Over-all dimensions should be placed outside the intermediate dimensions (Figs. 23, 28, and 35). In dimensioning with tolerances, if an over-all dimension is used, one intermediate distance should not be dimensioned.

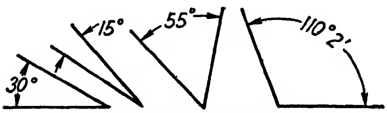


FIG. 34.—Dimensioning angles.

For dimensioning in limited space the arrowheads should be reversed, and methods shown in Fig. 33 may be used.

In dimensioning angles an arc should be drawn, and the dimension placed so as to read from the horizontal position (Fig. 34).

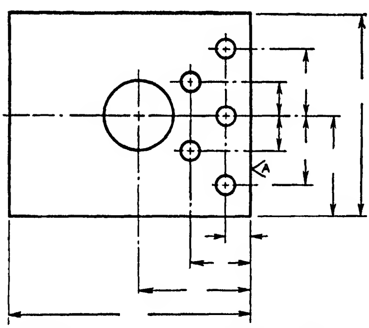


FIG. 35.—Always dimension from an easily established base line.

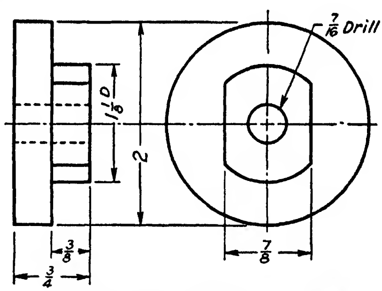


FIG. 36.—Dimensioning circles.

An exception is sometimes made in the dimensioning of large areas when the dimensions are placed along the arc.

Dimensioning Circles.—A dimension indicating the diameter of a circle should be followed by the abbreviation *D* except when it is obvious from the drawing that the dimension is a diameter (Fig. 36). The dimension of a radius should always be followed by the abbreviation *R* (Fig. 37). The center should

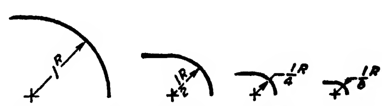


FIG. 37.—Showing dimension of a radius.

be indicated by a cross or circle, and the dimension line have one arrowhead.

Dimensioning Holes.—Holes that are to be drilled, reamed, punched, swaged, cored, etc., should have the diameter, given preferably on a leader, followed by the word indicating the operation, and the number of holes to be so made (see Fig. 38).

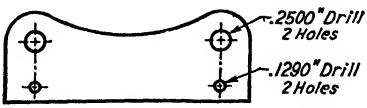


Fig. 38.—Give full information as to holes.

Holes that are to be machined after coring or casting should have finish marks and finished dimensions specified. For counterbored holes the diameters and depths should be given, and for countersunk holes the angles and diameters should be given (see Figs. 39 and 41).

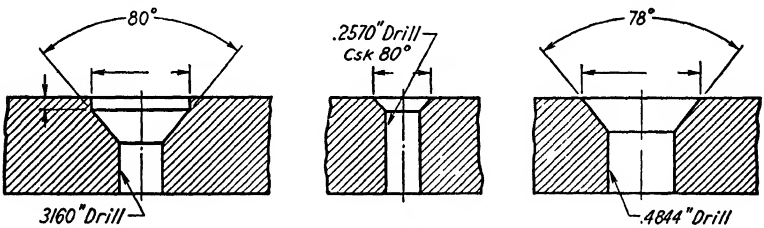


Fig. 39.—Dimensioning counterbored and countersunk holes.

If needed by the shop on account of the method of laying out, as in the button method, the chordal distances between holes on a bolt circle or the center-to-center distances between holes located by coordinates should be calculated and dimensioned in decimals.

Dimensioning with Tolerances.—Accurate dimensions which are to be established with limit gage or micrometer should be expressed in decimals to at least three places, and the drawing should give the limits between which the actual measurements must come (see Figs. 40 and 41). For external dimensions the maximum limit is placed above the line, and for internal dimensions the minimum limit is placed above the line. This method should be used for smaller parts and where gages are extensively employed.

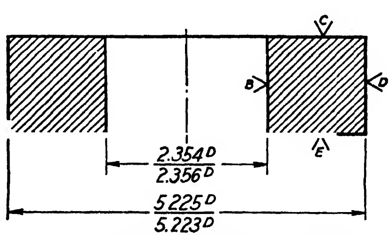


Fig. 40.—Where one view is sufficient.

A second method, used for larger parts and where few gages are employed, is to give the calculated size to the required number of decimal places, followed by the tolerances plus and minus, with the plus above the minus, as $8.625\text{D}^{+0.030}_{-0.002}$.

Use of Notes and Tables.—The legibility and appearance of drawings may often be improved by specifying dimensions representing a series of tool operations by notes instead of by figured dimensions. Figure 41 illustrates several examples.

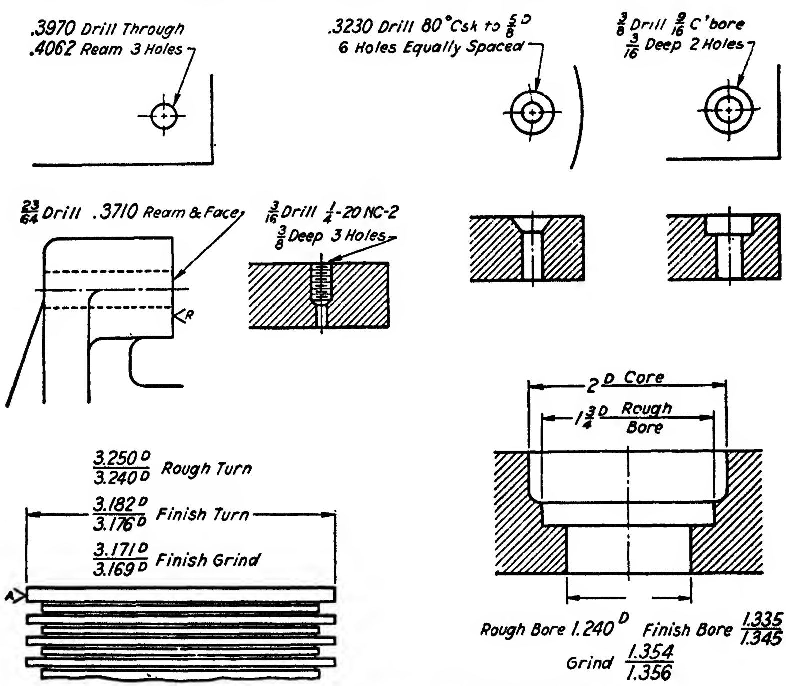


FIG. 41.—Dimensioning to show tolerances.

On a drawing, if a dimension must be changed, the changed figures should be underlined or otherwise marked. It is customary to note changes in dimensions in a tabulation on the drawing and to refer to them by letters or symbols placed after the altered dimensions. Date of change is also frequently given.

Notes, in addition to dimensions, should be given wherever clarity demands. All notes should preferably read horizontally.

Dimensioning Fits.—The dimensions and tolerances given in the detail drawings of the two parts of a cylindrical fit will deter-

mine the clearance (or interference) between these parts. Whenever possible, the tolerances and the allowance for a desired fit should conform to those set up in the American Standard for Tolerances, Allowances, and Gages for Metal Fits. The classes of fit there specified may be indicated on assembly drawings.

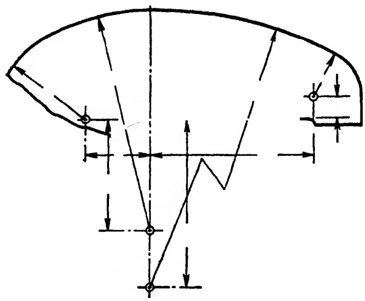


FIG. 42.—Dimensioning curves and angles.

Dimensioning Tapped Holes and Threaded Parts.—These parts should be specified, in general, by reference in notes to the American Standard Coarse, American Standard Fine, and American Standard Special Screw Thread Series with full reference to the class of fit desired.

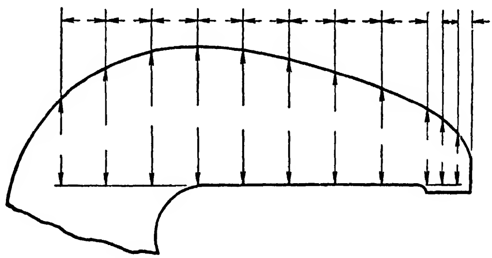


FIG. 43.—Another method.

Curves and Angles.—A curved line may be dimensioned either by radii or by offsets (Figs. 42 and 43).

When angular dimensions are necessary, a horizontal (or vertical) center line should be used as a base line, but not both, and points located from it (Fig. 44).

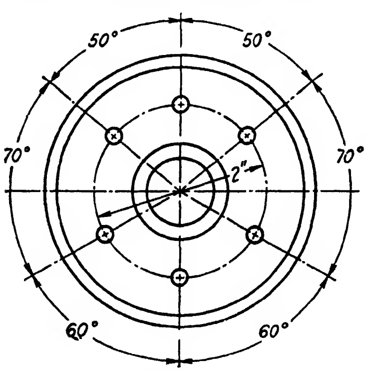


FIG. 44.—Use only one base line.

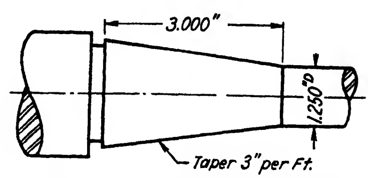


FIG. 45.—Dimensioning tapers.

If holes are to be equally spaced, one only should be located, and a note added, for example, "6 holes equally spaced."

Dimensioning Tapers.—The difference in diameter or width in one foot of length is known as the "taper per foot." At least three methods of dimensioning tapers are in general use.

Standard Tapers.—Give one diameter or width, the length, and insert note on drawing designating the taper by number taken from American Standards Association Bulletin B-5.

Special Tapers.—In dimensioning a taper when the slope is specified, the length and only one diameter should be given, or the diameters at both ends of the taper should be given, and length omitted (see Fig. 45).

Precision Work.—In certain cases where very precise measurements are necessary, the taper surface, either external or internal,

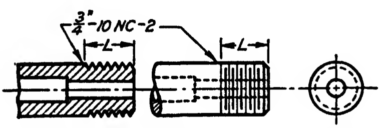


FIG. 46.—Thread symbols, regular.

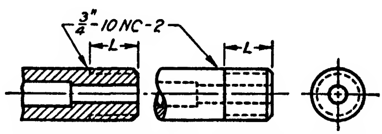


FIG. 47.—Thread symbols, simplified.

is specified by giving a diameter at a certain distance from a surface and the slope of the taper.

Finish Marks.[1]—A surface to be machined or "finished" from unfinished material, such as a casting or a forging, should be marked with a 60-deg. V, the bottom of the V touching the line representing the surface to be machined or finished. A code figure or letter should then be placed in the opening of the V to indicate the quality of the finish desired (see *A*, *B*, *C*, *D*, *E*, and *R* on Figs. 35, 40, and 41). The meaning of these code figures or letters should then be indicated by notes at the bottom or side of the drawings.

Screw-thread Representations for Bolts and Threaded Parts.

Thread Symbols, Regular.—Figures 46, 48, and 52 show the regular method of representing screw threads recommended for general use on assembly and detail drawings. Except in sections

[1] A standard set of symbols for use with the V marks is now being developed by the Sectional Committee on Standardization of Classification and Designation of Surface Qualities (B46) organized under the procedure of the A.S.A. with the A.S.M.E. and the S.A.E. as joint sponsor bodies.

of external threads and invisible internal threads, the threads are indicated by alternate long and short cross lines at *right angles* to the axis representing the crests and roots of the thread, the short lines heavier than the long lines, or of equal weight if preferred,

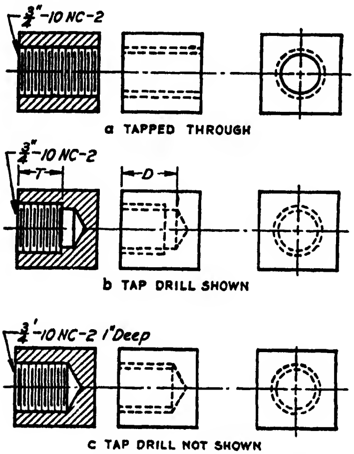


FIG. 48.—Thread symbols, regular.

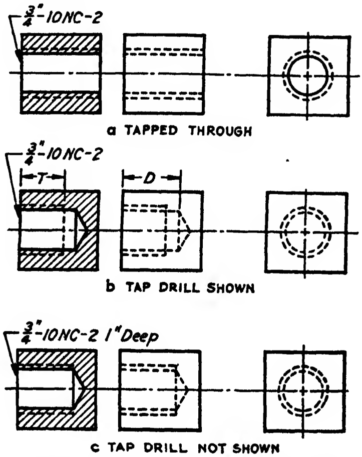


FIG. 49.—Thread symbols, simplified.

spaced by eye to look well. They need not represent the actual pitch.

Figures 46 and 48 show threads in section and elevation, with end view. Figure 46 shows external threads; Fig. 48(*a*) shows internal threads tapped through. Figure 48(*b*) shows internal threads where the tap-drill point does not go through. The drill point should be drawn at 60 deg. with the center line.

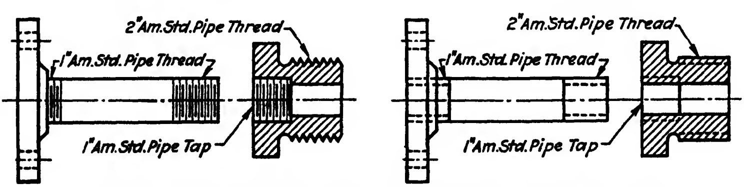


FIG. 50.—Pipe threads, regular method and simplified method.

The method shown in Fig. 48(*c*) should be used to indicate a bottoming tap, when depth of thread is the same as depth of drill or when it is not necessary to specify both depth of drill and depth of thread. Figure 49 shows an assembly of threaded parts.

Thread Symbols, Simplified.—Figures 47 and 49 show the simplified symbol method of screw-thread representation. This method may be adopted where it is desirable to simplify drafting work. The threaded portion is indicated by lines made of short dashes, drawn parallel to the axis at the approximate depth of the thread. This simplified method is not recommended for either exterior or sectional views of assembled parts.

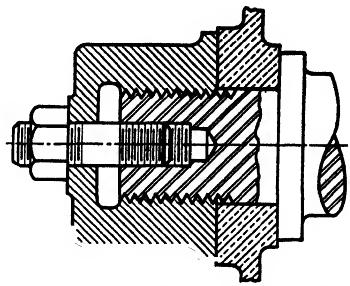


FIG. 51.—Assembly of threaded parts.

The size and length of thread and depth of tap should be given on the drawing. Threads are always considered to be "right hand" unless specified as "left hand," or "L H." Bolt ends should be shown as flat and chamfered to the thread depth at 35 deg. (drawn 30 deg.) with the flat surface.

Pipe Threads.—Pipe threads should be represented in the same manner as bolt threads (Fig. 50). It is not necessary to indicate taper, but this may be done if desired. Dimensions of standard pipe threads, including diameters and form and length of thread and taper, may be found in the American Standard for Pipe Threads to which reference should be made on the drawing.

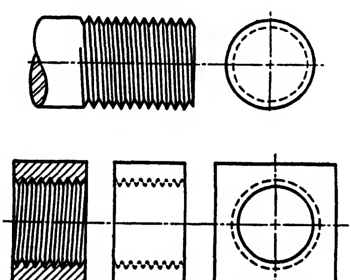


FIG. 52.—Conventionalized thread pictures.

Thread Pictures.—When it is desirable to use "thread pictures," it should be done as in Fig. 52. The helices are conventionalized into slanting straight lines, and the contour shown as a sharp V at 60 deg., although the standard threads are truncated at the top and filled in at the root. Details of standard threads will be found in American Standard for Screw Threads.

Bolt Heads and Nuts.—Exact dimensions of American Standard rough, semifinished, and finished bolt heads and nuts, Regular series and Heavy series, will be found in the American

Standard for Wrench Head Bolt and Nuts and Wrench Opening. For the purposes of drawings, these sizes are approximated.

STANDARDIZING DRAWINGS FOR FIXTURE

Cost of fixtures has much to do with their design and use. Methods which will keep the costs as low as possible are of vital importance in all cases. To this end all plants that build fixtures in any quantity have a standard procedure which fits the great majority of cases and enables costs to be estimated without difficulty. Where the work warrants they have standard sizes of angle plates, channels, or other forms used in holding the work. These are usually of cast iron and are carried in stock to some extent, so as to be available when needed. Since welding has become so common in most shops, many use this method to build plate steel into any sort of angle, channel, or box that may be needed. As in most cases, there are wide differences of opinion regarding the merits of the two systems.

Practice also differs regarding the making of drawings. Many still use inked tracings on cloth, while others find pencil tracings on bond paper perfectly satisfactory. Blueprints are used in both cases, so that the only choice seems to be in the matter of permanent record when they are necessary. The minimum-size sheet is a standard letter-sheet size, 8½ by 11 in., which makes it convenient for filing. This size is also convenient when drawings or blueprints must be mailed. Larger sheets are in multiples of the small size, as 11 by 17, 17 by 22, and 22 by 34 inches. These fold for filing or mailing when desired. The practice of the Taft-Peirce Mfg. Co., Woonsocket, R. I., is to use pencil on bond paper, with the following instructions to their tool designers:

Bond paper is used for all drawings unless otherwise ordered, lines, etc., to be made as follows:

Visionary or subject lines—Fine red pencil.

Tool outlines—Very heavy sharp pencil line.

Margin lines—Very heavy solid black pencil line ¼ in. from edge of paper.

Center lines—Solid fine pencil line.

Witness and dimension lines—A fine pencil line.

Dimension figures, arrowheads, titles, F marks, and notes to be printed in pencil.

Figures and letters to be formed clearly, distinctly, and of uniform size.

Figure all accurate dimensions, as for bushings, etc., from bedding surface of part.

Workmen should not be obliged to add, subtract, etc., in order to obtain measurements.

Dimensions and dimension lines to be outside the outline of the part wherever practicable.

Do not repeat dimensions.

Omit dimensions in assembly when they can be given in detail.

Out-of-scale dimensions are to be underlined.

Omit pattern dimensions, except over-all dimensions, on tool drawings. Pattern maker will measure the prints; consequently detail drawings of castings must be made accurately to scale.

Detail all parts that are made especially for the job.

Group all flat work together.

Group all round work together.

Symbol numbers in pencil and enclosed in a circle are to be placed close to each part on both assembly and detail.

Notes are printed horizontally in pencil and underlined with pencil.

Titles—When not already printed on the blank sheets should be stamped with the rubber-stamp form provided. Print all titles at the lower right-hand corner, and have the long dimension of the paper always at the top and bottom.

Scale—When a drawing is made to any other scale than full size, the scale should be plainly indicated above its title, thus: "Scale ½ size," or "Scale 4 to 1."

Quality—Do all work neatly, and keep drawings clean. This is very important.

Sizes—Drawing sizes are designated as follows:

A size	8½ × 11	
B size	11 × 17	
C size	17 × 22	Outside dimensions
D size	22 × 34	
E size	34 × 44	

Larger sizes, special, usually 36 in. wide by any length.

Details—Keep entire job on one sheet where practicable; but where it becomes necessary to use separate sheets, try to use same-size sheets.

All screws, nuts, pins, and other stock parts to be marked "Cyanide" or "Pack harden" when heat treatment is required.

On part and tool drawings after making a change or correction describe same under the head of "Alterations" in the corner of the drawing, at the same time adding a small symbol letter in a circle which

should correspond to a similar symbol placed close to the change in drawing.

Form tools—All circular form tools to show side clearance. The side angle of form tools to be made as slight as possible consistent with free cutting, generally from 1 to 2 deg. The shape of the tools will largely determine the angle of side clearance. Angle of end clearance about 10 deg.

Give limits on all important dimensions on both tool and part drawings, using plus and minus signs to express the amount of tolerance above and below the nominal figure, thus: ± 0.001 or $+0.001$ or -0.001 -0.000 $+0.003$.

In specifying stock, for use on tools, call for cold-rolled steel wherever practicable, as it does away with unnecessary machining operations.

If a piece is to be pack hardened and is apt to go out of shape, machinery steel is better, having less internal strains than cold-rolled steel.

Symbols for Castings

C.I. Cast iron for general use.

M.C.I. Medium cast iron. Close-grained clean iron for use where especially sound castings are required. Use only in large castings.

M.I. Malleable iron—6 weeks delivery.

S.S.C. Semisteel castings. Can be bent hot—6 weeks delivery.

S.C. Steel castings—1 week delivery.

B Bz. Bronze, mixture B. This is a fairly hard bronze, suitable for bearings and castings where a fairly hard metal is required.

88 per cent copper	2 per cent zinc
9 per cent tin	1 per cent lead

C Bz. Bronze, mixture C—This is a miscellaneous mixture and suitable for ordinary castings such as brackets, levers, and castings not requiring a high tensile strength. Not suitable for bearing metal.

85 per cent copper	9 per cent zinc
4 per cent tin	2 per cent lead

D Brass. Yellow brass, mixture D

62 per cent copper	37 per cent zinc
1 per cent tin	

H Bz. Bronze, mixture H—This is specified by U. S. government for bearing metal. It is very hard.

82 per cent copper	4 per cent zinc
14 per cent tin	

Ph. Bz. Phosphor bronze

90 per cent copper 10 per cent phosphor tin

Symbols for Bar Stock

B.B.R. Bright Bessemer rod. Soft steel. 10-ft. lengths.

D.R. Drill rod. Tool steel for drills and small cutting tools. 3-ft. lengths.

T.S. Tool steel.

H.S.S. High-speed steel.

T.S. 7-ct. base. Mild tool steel for mandrels, etc., not requiring a cutting edge.

M.S. 0.15 to 0.35 per cent carbon steel for general use.

C.R.S. Cold-rolled steel.

W.I. Wrought iron. Best for parts to be casehardened.

C.I. The stock department carries a limited supply of cast-iron bars. Both round and rectangular.

CHAPTER II

ADVANTAGES OF TOOL-DESIGN STANDARDS

The establishment of a complete and thorough system of putting full information on all drawings is a great saving in the making of all kinds of tools. This is true in shops of all sizes, although the following example is from a large concern, the Westinghouse Electric & Mfg. Co. As pointed out by J. J. Huber, one of their engineers, the combination of having five widely separated design offices and one large toolmaking department makes such system a necessity.

To develop, maintain, and improve this plan, a standard-parts and -design book was made up and furnished each tool designer. This book proved rather inexpensive, as it consisted mostly of roto prints, $8\frac{1}{2}$ by 11 in. Each book is numbered, and the owner held responsible for its condition. A single book is ample for two or three men, but owing to low cost, individual responsibility, handiness, and for sanitary reasons each man was furnished with a book.

In working up a design, especially a fabricated structure, the thickness of the plate or the size of rolled section involved is selected from the listed sizes stocked by the company. This saves delay in securing materials and unnecessary machining. These listed sizes are carried in the fabricating section of the tool department. A sheet showing the proper fillet welds for the various thicknesses of plates is also available for the tool designer.

For drill jig work there are several sheets covering "stocked" and design-standard drill bushings. On each bushing sheet a sample bill of material is shown, indicating how the bushings should be specified on the jig drawing. If the bushing wanted is carried in the storeroom, it will be marked as "stock"; but if it is not carried, reference is made only to the tool-standard sketch. No detailing of the bushing is required, as each group leader in the toolmaking department has a book, the same as the tool designer, thus saving designing, material-ordering, estimating, and cost-computing time. Fixtures, molds, dies, and benders

are considered in the same way, applying necessary information from sheets on standard bolt slot, keys, lining-up pins, stripper bolts and screws, punches, and springs.

Details of the quick-acting hand nut illustrated in Fig **53**, are given on a reference drawing only, as it is not used often enough to warrant carrying it in stock. A cheap but efficient method of securing guide- or leader-pin bushings in die shoes is also shown in Fig. 54. This method can also be used for drill jigs where the number of pieces does not warrant a permanent jig.

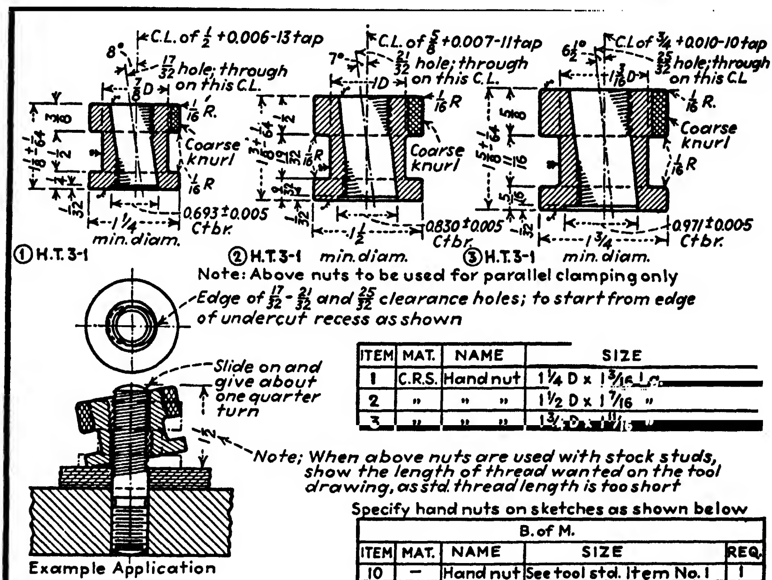
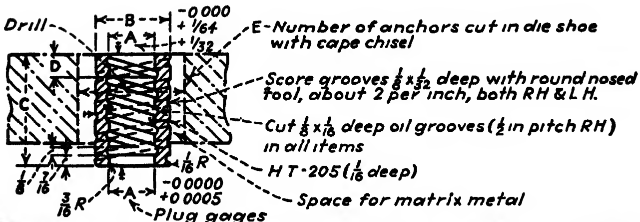


FIG. 53.—Details of a quick-acting hand nut that requires but a quarter turn to operate.

All designs of special tools are made in pencil on special printed paper forms, showing general manufacturing information, bill of material column, and a title. Standard, stocked cutting tools, however, are traced with ink on cloth and are generally of the tabulated form. Details of slip bushings used for some work are shown in Fig. 55. This also shows the fixed bushing, or sleeve.

Sheets covering various treatments of tool and low-carbon steels, tolerances, finishes, and fits are given to the tool designer so that he can furnish this information on the tool drawing.



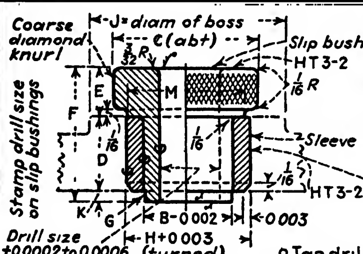
ITEM	SIZE	A	B	C	D	E	DRILL	MAT	SIZE	REQ	LIMIT PLUG GAGE
1	1 x 2½	10000	1⅝	2½	–	8	2⅛	C R S P.D.1556	1¾ D x 2⅝ In Lg	1	62163-081
2	1¼ x 3	12500	1⅞	3	–	10	2⅜	H R S P.D.1555	2 D x 3⅛ In Lg	1	81143-J8
3	1½ x 1½	15000	2¼	1½	–	12	2¾	C R S P.D.1556	2¼ D x 1⅝ In Lg	1	81143-E11
4	1½ x 2	"	"	2	–	"	"	"	" x 2⅛ " "	1	" "
5	1½ x 2½	"	"	2½	–	"	"	"	" x 2⅝ " "	1	" "
6	1½ x 2¾	"	"	2¾	½	"	"	"	" x 2⅞ " "	1	" "
7	1½ x 3¼	"	"	3¼	1	"	"	"	" x 3⅜ " "	1	" "
8	2 x 2¾	20000	2¾	2¾	–	16	3⅜	"	2¾ D x 2⅞ " "	1	81143-J6

Specify bushings on sketches as shown below

B of M				
ITEM	MAT	NAME	SIZE	REQ
12	Stock	Guide Pin Bush	1½ x 2¾	4

All items carried in stock

FIG. 54.—Easy method of fastening guide-pin bushings in die shoes by using a matrix metal.



Specify bushings on tool drg as shown below

ITEM	MAT	NAME	SIZE	REQ
20	–	⅞ slip bush	See tool std item No	1
21	–	⅝ slip bush	Use std bushing	–
22	Stock	Sleeve	1¼" S F	4

Specify thus, when bushings are available in dept's toolroom

Grind outside diam to suit bored hole

Note Special length bushings should be designed 1/32 larger on B diam

○ Tap drill ⊖ Reamer drills * Sleeves carried in stock

	SLIP BUSHINGS											Plug Gage B	SLEEVES					
	Item	DRILL SIZE	B	C	D	E	F	K	M	Mat	Stock Size	Item		D	H	J		Mat	Stock Size
○	1	[illegible]	[illegible]	1⅝	1⅛	9/16	[illegible]	⅛	1⅜	No.3TS	1¾ D x 1⅝ Lg	16*	1¼ S.F	1⅛	1635	2¼	1625	No.3TS	1¾ D x Lg
⊖	2	.8065	"	"	"	"	"	"	"	"									
○	3	51/64	"	"	"	"	"	"	"	"									
	4	[illegible]	"	"	"	"	"	"	"	"									
⊖	5	[illegible]	"	"	"	"	"	"	"	"									
⊖	6	.869	"	"	"	"	"	"	"	"									
○	7	⅞	"	"	"	"	"	"	"	"									
○	8	[illegible]	[illegible]	1¼	1¼	9/16	2	3/16	1½	"	1⅞ D x 2[illegible] Lg	17*	1⅜ S.F	1¼	1760	3	1750	"	1⅞ D x Lg
⊖	9	.9315	"	"	"	"	"	"	"	"									
	10	15/16	"	"	"	"	"	"	"	"									
○	11	61/64	"	"	"	"	"	"	"	"									
⊖	12	63/64	"	"	"	"	"	"	"	"									
⊖	13	994	"	"	"	"	"	"	"	"									
	14		"	"	"	"	"	"	"	"									
○	15	[illegible]	[illegible]	[illegible]	[illegible]	⅝	2¼	3/16	[illegible]	"	2 D x 2¼ Lg	18*	1½ S F	[illegible]	[illegible]	3¼	1.875	"	2 D x Lg

FIG 55.—Standard slip bushings and the fixed bushing or sleeve.

The time required to show this additional and essential information on the tool drawing has proved very beneficial in lowering the cost of tool manufacture.

Standard Parts for Jigs.—A tool designer or maker should have a set of standard tables for his reference which insure the producing of a jig and its component parts all in proportion. It also reduces the cost of the jig and facilitates its delivery. For example, let us consider a tool designer having a set of standard angles, channels, round plate and round stock, bricks,

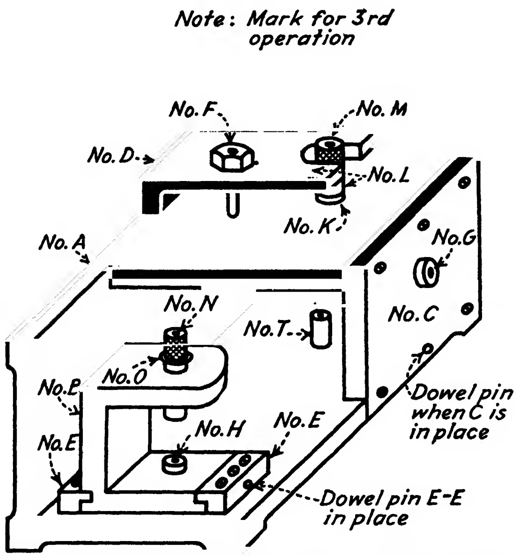


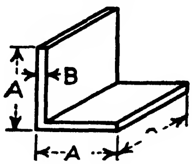
FIG. 56.—Example of use of standard cast channels in building up jigs.

plates, and square stock, as given in the accompanying tables (1 to 10). The proportion and range of sizes have been compiled for jig making only, and it is surprising how many jigs or fixtures can be built up from them.

As an example of the way in which these standard castings can be used, refer to Fig. 56, which shows quite an elaborate drill jig. This is made up of practically two standard channels, a plate, and standard bushings. For operating these bushings the standard wrenches can be used as shown. The large channel *A* has half of one side cut out and both the sides planed down to receive the plate *C*, which ties the sides of the channel together and also carries a drill bushing, as shown.

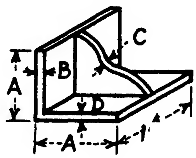
A smaller channel *B* is planed to slide under the gibs *EE* and allows the bushings to be adjusted as desired with reference to those carried in *A*. Almost innumerable combinations can be made in this way, and this also gives all examples of the per-

TABLE 1.—STANDARD ANGLE
In Inches



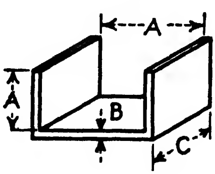
A	*B*	*C*
3	7/8	6
4	7/8	6
6	1	6
6	1¼	12
8	1	8
8	1¼	12
10	1¼	10
12	1¼	12
14¼	1⅛	7
13	1¼	12

TABLE 2.—STANDARD ANGLE
In Inches



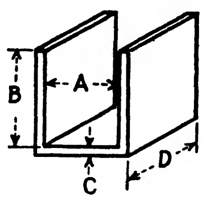
A	*B*	*C*	*D*
6	1	5/8	1
6	1½	7/8	1
8	1	5/8	1
12	1¼	7/8	1

TABLE 3.—STANDARD CHANNEL
In Inches



A	*B*	*C*
1¼	¾	6
1¾	7/8	8
2¼	1	10
3	7/8	12
4	1	14
5	1¼	14
6	1¼	20
7	1¼	20

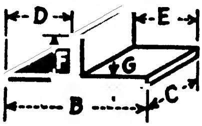
TABLE 4.—DEEPER CHANNEL
In Inches



A	*B*	*C*	*D*
1¼	3	¾	6
1½	4	1⅜	14
1¾	4	7/8	8
2¼	5	1	12
2¾	6	1⅛	12
3½	7	1	12
4	8	1	14
5	7	1¼	13
6¼	4	1¼	7
6¾	5	1	8
7¾	6	1¼	6

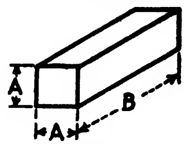
spective sketching in connection with this system. Tables 11 to 18 inclusive show standard sizes for handles.

TABLE 5.—STANDARD TEE
In Inches



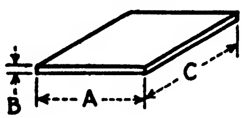
B	*C*	*D*	*E*	*F*	*G*
10⅜	5⅛	5 15/16	5 15/16	6⅝	1 5/16
14½	6⅛	6¼	6¼	7¾	1⅜

TABLE 6.—STANDARD SQUARE
In Inches



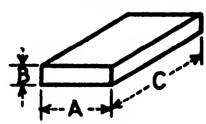
A	*B*	*A*	*B*
1	6	3	12
1½	10	4	12
2	10	5	12
2½	12		

TABLE 7.—STANDARD PLATE
In Inches



A	*B*	*C*
3	1	10
3	1	22
4	·1	12
4	1	24
5	1½	12
6	1	12,
6	1¼	34
7	1⅝	48
8	1	12
9	1⅛	14
10	1⅛	24
12	1⅛	24
12	1¾	12
13	1½	28
14	1	14
16	1¼	16
18	1	18
20	1⅛	20

TABLE 8.—STANDARD BRICK
In Inches



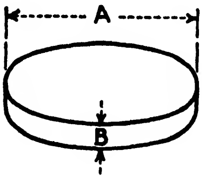
A	*B*	*C*
3	1½	6
3½	2	7
4	2½	8
4	2	10
3¼	2¼	15¼
4½	2½	9
7	2½	12
9	5	18

Handles for Jigs and Fixtures.—Handles for jig, fixture, or other machine application can now be purchased in standard sizes, the same as bushings for drilling jigs. Standard dimensions

for various types of handles, as supplied by the Cincinnati Ball Crank Co., are shown in Tables 13 to 18.

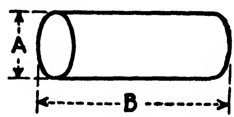
The tolerances to which these handles are made are also shown for the convenience of those who may wish to design fixtures in which handles of this kind can be used.

TABLE 9.—STANDARD ROUND
In Inches



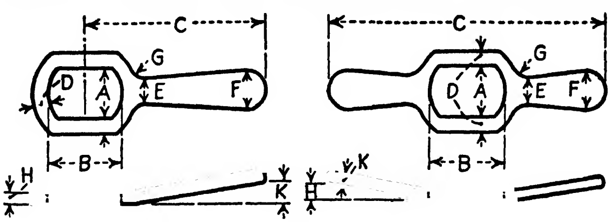
A	B
8	1
10	1½
12	2
14½	1½
16	2¼
22	1

TABLE 10.—STANDARD BAR
In Inches



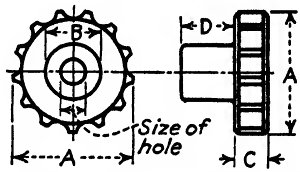
A	B
¾	10
1	4
1½	8
2	6
2½	10
3	8
4	10
5	10
6	12

TABLE 11.—SINGLE- AND DOUBLE-HANDLED JIG WRENCHES



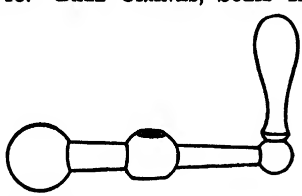
Single handle									Double handle								
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*K*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*K*
7/8	1 3/8	3½	5/16	½	¾	½	¼	½	2	2½	9	7/16	7/8	1	½	½	3/8
1	1½	3½	5/16	½	¾	½	¼	½	2¼	2¾	9	7/16	7/8	1	½	½	3/8
1¼	1¾	4	5/16	5/8	7/8	½	¼	½	2¾	3¼	10	½	7/8	1	½	½	3/8
1 5/8	2 1/8	4½	3/8	¾	1	½	¼	½	3	3½	10	5/8	7/8	1	½	½	3/8

TABLE 12.—MALLEABLE-IRON JIG KNOBS
In Inches



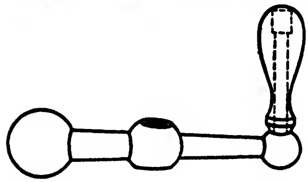
Size of hole	A	B	C	D
1/4	1 1/2	3/4	3/8	1/2
5/16	1 1/2	3/4	3/8	1/2
3/8	1 1/2	3/4	3/8	1/2
7/16	1 1/2	3/4	3/8	1/2
1/2	2	1 1/16	1/2	1/2
9/16	2	1 1/16	1/2	1/2
5/8	2	1 1/16	1/2	1/2
3/4	2 1/2	1 1/4	5/8	5/8
7/8	2 1/2	1 1/4	5/8	5/8

TABLE 13.—BALL CRANKS, SOLID HANDLES



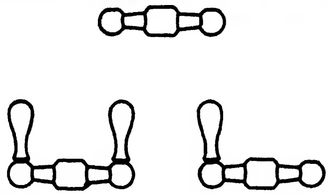
Size	Length over all, in.	Center ball, in.	Large end ball, in.	Small end ball, in.
0	3	7/8	1	5/8
1	3 1/2	1	1 1/8	3/4
1 1/2	4	1 1/8	1 1/4	13/16
2	4 1/2	1 1/4	1 3/8	15/16
3	5	1 5/16	1 1/2	1
4	5 1/2	1 5/16	1 1/2	1
5	6	1 3/8	1 5/8	1
6	6 1/2	1 3/8	1 5/8	1
7	7	1 7/16	1 3/4	1
8	7 1/2	1 1/2	1 3/4	1
9	8	1 1/2	1 3/4	1 1/16
10	8 1/2	1 9/16	1 3/4	1 1/8
12	11	1 13/16	2	1 1/4
13	13	1 15/16	2	1 1/4

TABLE 14.—REVOLVING HANDLES



Size	Length over all, in.	Center ball, in.	Large end ball, in.	Small end ball, in.
1	3½	1	1⅛	¾
1½	4	1 ⅛	1¼	1 3/16
2	4½	1 ¼	1⅜	1 5/16
3	5	1 5/16	1½	1
4	5½	1 5/16	1½	1
5	6	1 ⅜	1⅝	1
6	6½	1 ⅜	1⅝	1
7	7	1 7/16	1¾	1
8	7½	1 ½	1¾	1
9	8	1 ½	1¾	1 1/16
10	8½	1 9/16	1¾	1 ⅛
12	11	1 13/16	2	1 ¼
13	13	1 15/16	2	1 ¼

TABLE 15.—COMPOUND REST HANDLES

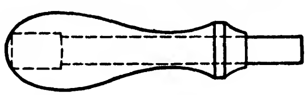


Size	Length over all, in.	Center ball, in.	End ball, in.
000	2½	13/16	5/8
1	2½	1 1/16	¾
4	3	1 1/16	¾
7	3½	1 1/16	¾
10	4	1 3/16	7/8
00	2½	13/16	5/8
2	2½	1 1/16	¾
5	3	1 1/16	¾
8	3½	1 1/16	¾
11	4	1 3/16	7/8
0	2½	13/16	5/8
3	2½	1 1/16	¾
6	3	1 1/16	¾
9	3½	1 1/16	¾
12	4	1 3/16	7/8

TABLE 16.—MACHINE HANDLES

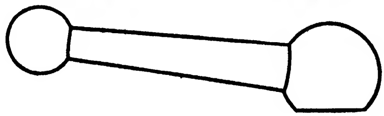
Size	Length of shank, in.	Length over all, in.	Diameter of shank, in.
000	7/16	1 23/32	1/4
00	7/16	1 29/32	1/4
0	7/16	2 5/32	5/16
1/2	7/16	2 7/16	5/16
1	9/16	2 11/16	3/8
2	1 1/16	3 1/16	7/16
3	1 1/16	3 7/16	7/16
4	1 1/16	3 29/32	7/16
5	1 3/16	4 1/4	7/16
6	1 5/16	4 9/16	1/2
7	1 5/16	5	1/2
8	1 3/16	5 3/4	5/8

TABLE 17.—REVOLVING MACHINE HANDLES



Size	Length of shank, in.	Diameter of shank, in.	Length over all, in.
1	9/16	5/16	2 5/8
3	3/4	3/8	3 25/32
4	3/4	7/16	4 1/32
7	1	1/2	5 1/8

TABLE 18.—TWO BALL LEVERS



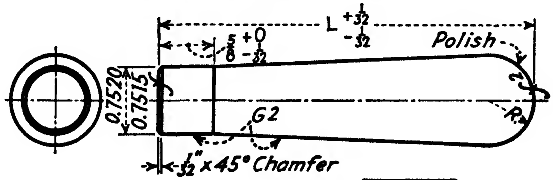
Size	Length over all, in.	Large end ball, in.	Small end ball, in.
1	3½	1⅛	¾
1½	4	1¼	13/16
2	4½	1⅜	15/16
3	5	1½	1
4	5½	1½	1
6	6½	1¾	1
7	7	1¾	1
10	8½	1¾	1 ⅛

BALCRANK HANDLE SPECIFICATION TOLERANCES

Machine handles, shank diameter.....	+0.001 to +0.003
Machine handles, shank length.......	−0.005 to +0.005
On machining of center or end balls:	
Holes up to and including ⅝ in.....	−0.0005 to +0.001
Holes over ⅝ in..................	−0.0005 to +0.0015
Thickness from face to face........	−0.0050 to +0.0050
Keyway width....................	−0.0000 to +0.0005
Keyway depth....................	−0.0000 to +0.0080
Diameter of faces.................	−0.0156 to +0.0156

Limits can not be held on thickness of ball and both face diameters. Specify only two of these diameters. Do not specify close tolerances where they are not needed; it is an economic waste.

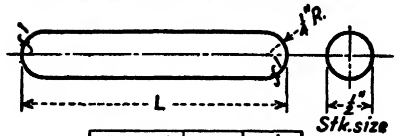
TABLE 19.—SPOKE FOR PILOT WHEEL



STEEL

L	R
4¼	½
3⅛	7/16

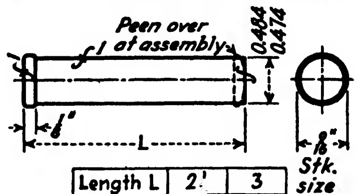
TABLE 20.—PIN FOR HAND SCREW



Length L	3	4½
Part No.	63-T	64-T

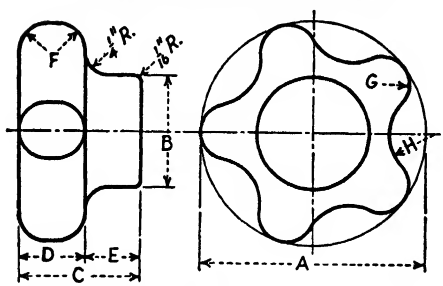
Mat'l: S.A.E.1112 Steel Hardened

TABLE 21.—PIN FOR HAND SCREW AND NUT



Length L	2½	3
Part No.	X	X

TABLE 22.—STAR KNOB BLANK



A	B	C	D	E	F	G	H
2½	1¼	1⅜	¾	⅝	5/16	5/16	½
4	2	2	1⅛	⅞	7/16	7/16	⅞

Mat'l: Cast steel

TABLE 23.—STAR KNOB

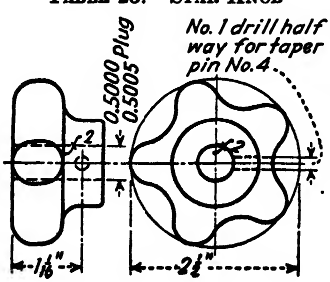
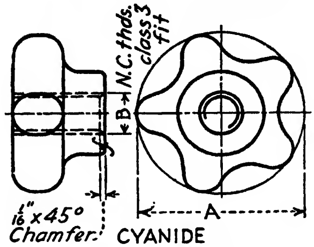


TABLE 24.—HAND KNOB



A	B	Thds. per in.
$2\frac{1}{2}$	$\frac{1}{2}$	13
$2\frac{1}{2}$	$\frac{5}{8}$	11
4	$\frac{3}{4}$	10
4	$\frac{7}{8}$	9
4	1	8

TABLE 25.—USE OF PILOT WHEELS

Diam. of Shafts	Pilot Wheels	Ball Face Washers	Ball Seat Washers
$\frac{3}{4}$	1910-T	1904-T	1903-T
1	1911-T	1905-T	1902-T
$1\frac{1}{8}$	1912-T	1906-T	1913-T

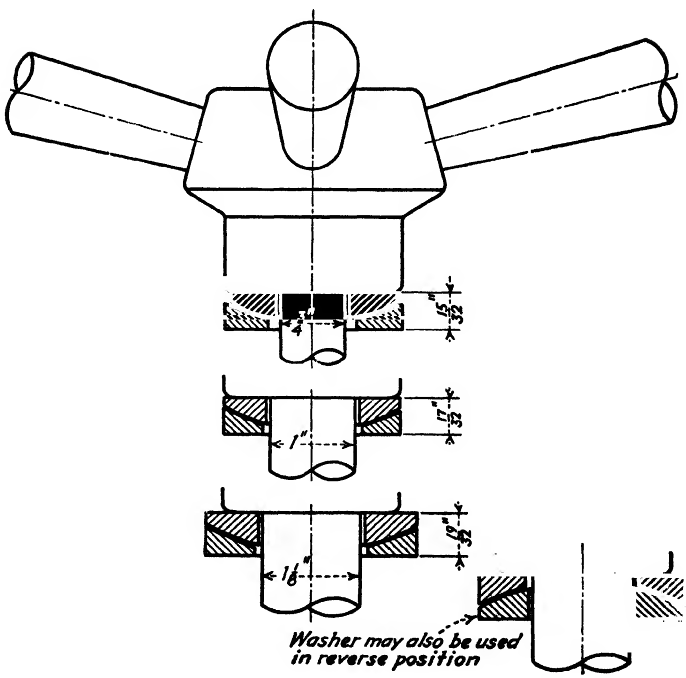
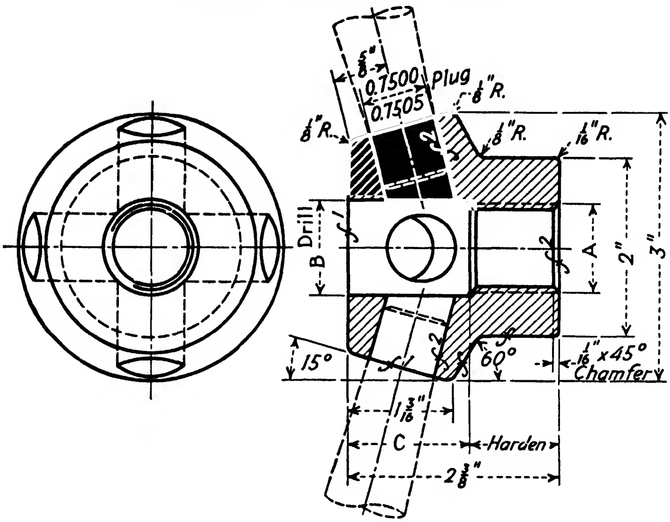


TABLE 26.—PILOT-WHEEL DETAILS



A	Thds.-Inch	B	C
3/4	10	13/16	1 1/2
1	8	1 1/16	1 1/8
1 1/8	7	1 3/16	1 3/8

Standard Parts for Fixtures.—Nearly all shops building fixtures or machinery have some standards for such parts as handles, star knobs, pilot wheels, and the like. By using standard parts for such work the cost of designing and of making the fixtures can be materially reduced. While these standards vary widely in design and in kind, some are given herewith as a basis from which any fixture designer can select those best suited to his particular line of work. In many shops these small parts are made up in quantity in the production department and kept in the toolroom, where they are instantly available when a fixture is to be made. In most cases the holes are only rough bored or even left blank, and the dimensions where fits are required are left for finishing when the fixture is made.

A few standard parts are shown in Tables 19 to 26, which give an idea of the way in which such standards are handled in a large plant, these being from the Cincinnati Milling Machine Co. The pilot wheel uses the spokes shown as well as the washers indicated.

More Standard Jig Parts.—The National Cash Register Co. use hundreds of jigs of various types. Many parts of these are standardized and are made up in quantity in their production department for use when needed. These parts are kept in conveniently located drawers and bins so that no time need be lost when they are needed. A number of their standards are shown in the following pages and contain many suggestions which can be used to advantage in many other shops.

Jig-lid stops, shown in Fig. 57, are very convenient when jigs with swinging or lifting lids are used. They prevent the lid

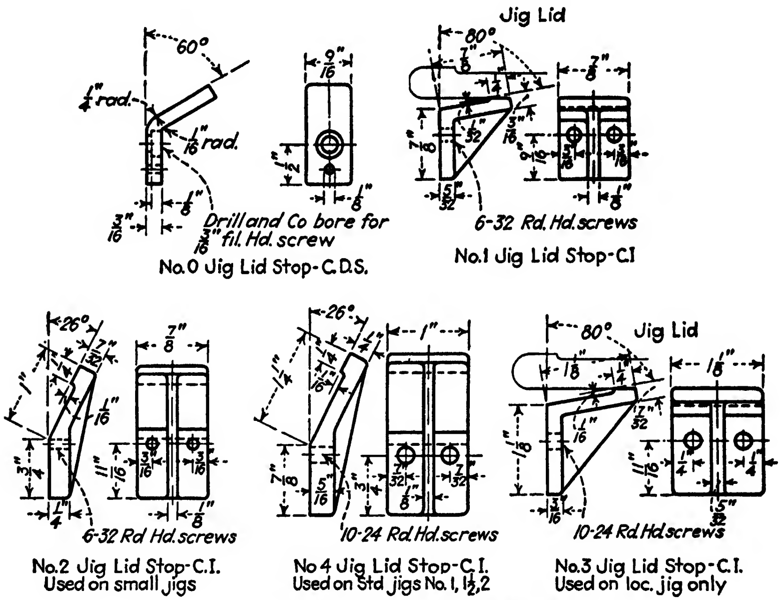
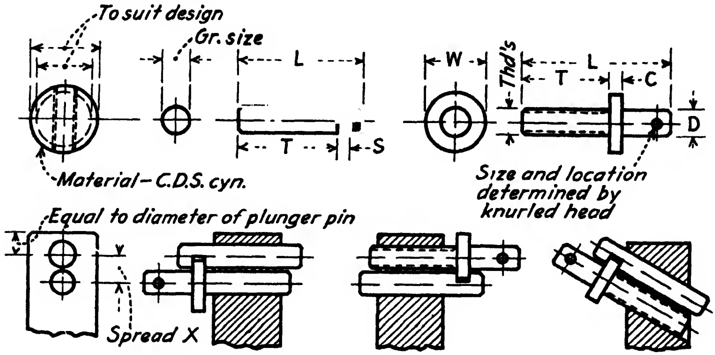


FIG. 57.—A variety of jig-lid stops.

from swinging farther than is necessary and are shown for use with jigs of various kinds and sizes.

It is sometimes necessary, or advisable, to hold work by direct pressure of a plunger instead of by a screw which also exerts a turning movement to the point of contact. In such cases a plunger-pin and collar-screw assembly has been found very satisfactory. Both the plunger pin and the collar screw are shown in Table 27 together with methods of application. The plunger pins are made of hardened and ground drill rod, while the collar screw is made from cold-drawn cyanided steel.

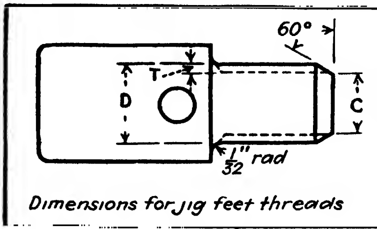
TABLE 27.—PLUNGER-PIN AND COLLAR-SCREW ASSEMBLY
Recommended When Direct Pressure Is Required Without Turning Action On Work



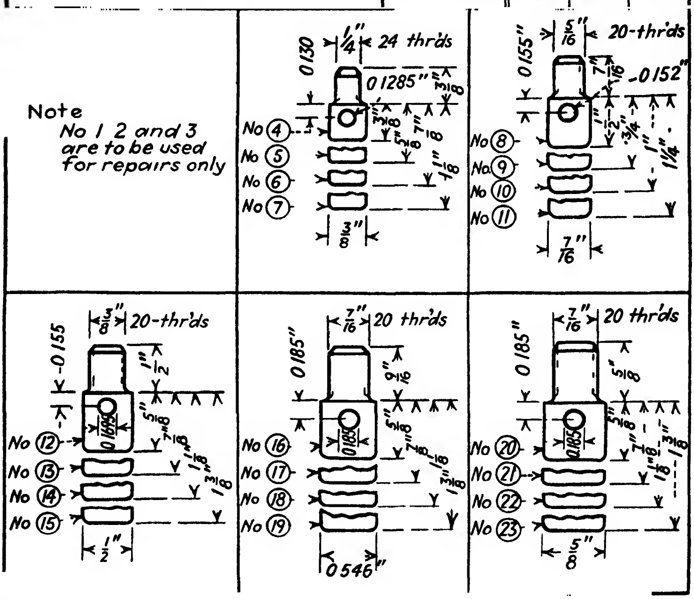
Plunger pin-material-D.R. hd'n Gr.						Collar-screw-material-C.D S. C Y N.					
		L.	T.	S.	x	Thd's	L.	T.	C.	W.	D.
3/16		1 1/8 1 5/16 1 1/2 1 11/16	7/8 1 1/16 1 1/4 1 7/16	1/8	7/32	3/16 32	1 3/8	3/4	7/64	27/64	3/16
1/4	●	1 1/2 1 3/4 2 2 1/4	1 1/4 1 1/2 1 3/4 2	1/8	● 9/32	1/4 24	1 3/4	1	7/64	35/64	1/4
5/16	●	1 1/2 1 13/16 2 1/8 2 7/16	1 1/4 1 9/16 1 7/8 2 3/16	5/32	● 11/32	5/16 20	1 7/8	1	9/64	43/64	5/16
3/8		2 2 3/8 2 3/4 3 1/8	1 11/16 2 1/16 2 7/16 2 13/16	3/16	13/32	3/8 20	2 7/16	1 1/4	11/64	51/64	3/8
7/16		2 1/4 2 11/16 3 1/8 3 9/16	1 7/8 2 5/16 2 3/4 3 3/16	1/4	15/32	7/16 14	2 3/4	1 1/4	15/64	59/64	7/16
1/2		2 1/2 3 3 1/2 4	2 1/8 2 5/8 3 1/8 3 5/8	1/4	17/32	1/2 12	3 1/8	1 1/2	15/64	1 3/64	1/2

Jig feet, to provide supports that raise the jig from the table and provide positive contact, are made in quantity and kept in the toolroom stock. They are all of tool steel and are screwed into the jig by means of a pin wrench for which a hole is provided. Lengths, diameters, and thread sizes are given in Table 28.

TABLE 28.—STANDARD JIG FEET



Feet No	D	T	C
1 2 3	0.1875	0.0271	0.1373
4 5 6 7	0.250	0.0361	0.1818
8 9 10 11	0.3125	0.0433	0.230
12 13 14 15	0.375	0.0433	0.2934
16 17 18 19	0.4375	0.0433	0.355
20 21 22 23	0.4375	0.0433	0.355



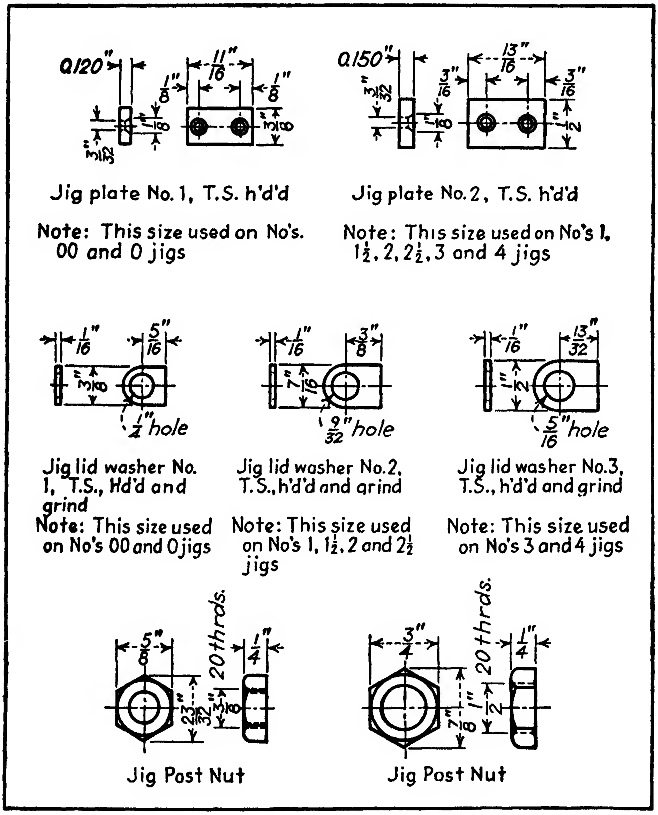
Jig plates, lid washers, and nuts are also standardized, as shown in Table 29. The plates are of tool steel and hardened. They are used for locating the work. The lid washers are also of tool steel, hardened and ground. They are used between the lid and the body of the jig. An application of these lid washers can be seen in Fig. 100. Jig-post nuts are shown in two sizes.

Thumbscrews for jig lids and jig posts are given in Fig. 58, with all necessary details. The jig posts are of cold-drawn steel,

carbonized and hardened at the upper end, after being tapped for the thumbscrews. The lower end is a press fit above the threads. These posts lock the lids in place while in use.

Stripper screw standards are given in Fig. 59. Four sizes are shown. The screws are made of cold-drawn steel.

TABLE 29.—JIG PLATES, WASHERS, AND NUTS



A group of die blanks, punch holders, round and rectangular stripper plates and subplates, and die blocks for compound dies are seen in Table 30. These require no explanation. In making up new dies for any job these parts are always available and save much time both in designing and in making up the new tools.

Guide pins, guide-pin bushings, felt washers, and retainers of varying size are shown in Tables 31 to 34 and in Fig. 60. All

pins made for stock are made on screw machines and finished on the centerless grinder. The shoulders are 45 deg. Special pins are lathe turned in the toolroom and have square shoulders. Drill rod is used for pins under ½ in. From ½ to 1 in. tool steel is used. Both sizes are hardened and ground. Larger pins are made of machine steel carbonized, hardened, and ground.

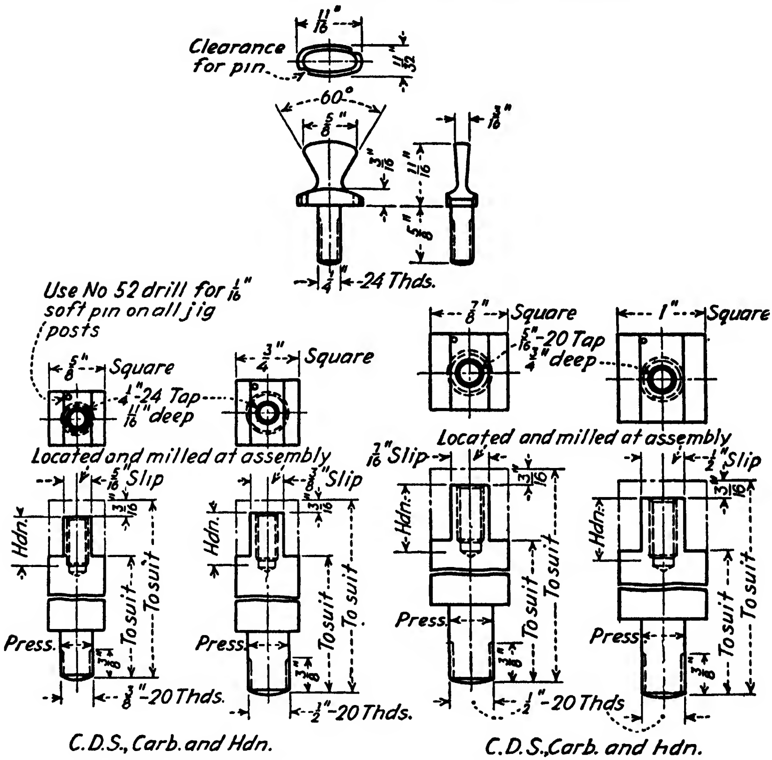


FIG. 58.—Thumbscrews and jig posts.

Standardized safety guards for punch presses when inverted dies are used are seen in Fig. 61. They are made in two parts, 1 and 2, left and right, respectively. They contain suggestions for other uses and for modified design.

The use of stripper guide pins is shown in Fig. 62. The parts are of tool steel, hardened and ground. The construction details show how they are used.

Small punches, made from drill rod or small wire, are backed up by thrust buttons of tool steel which are hardened. Die

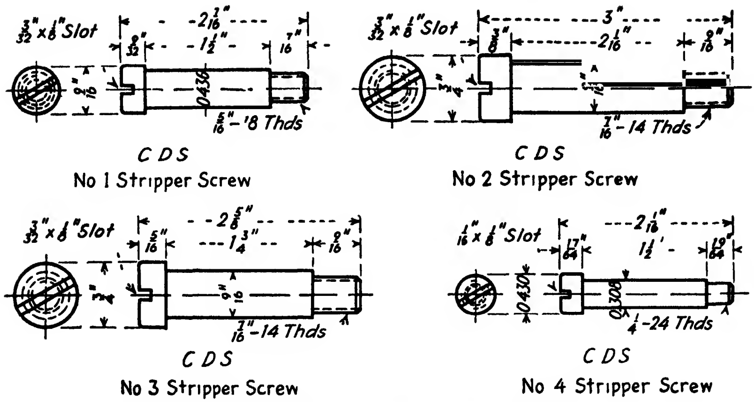


FIG 59 —N C R standard stripper screws

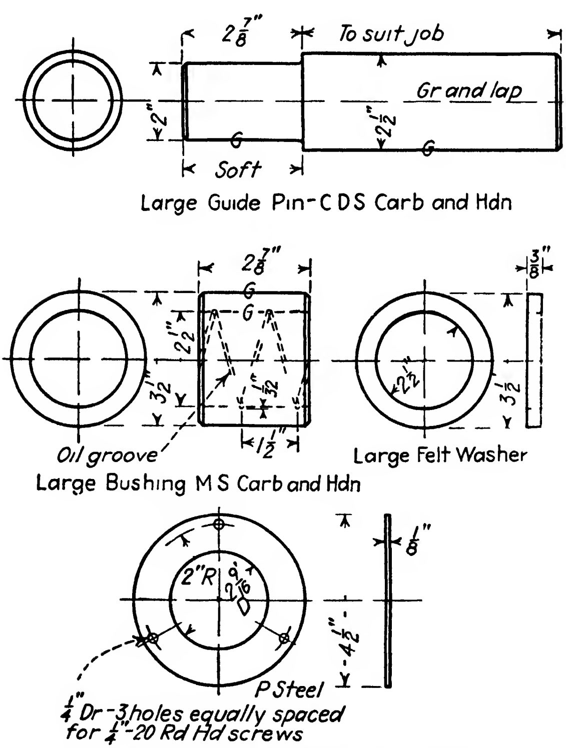


FIG 60 —Guide pins and guide-pin bushings

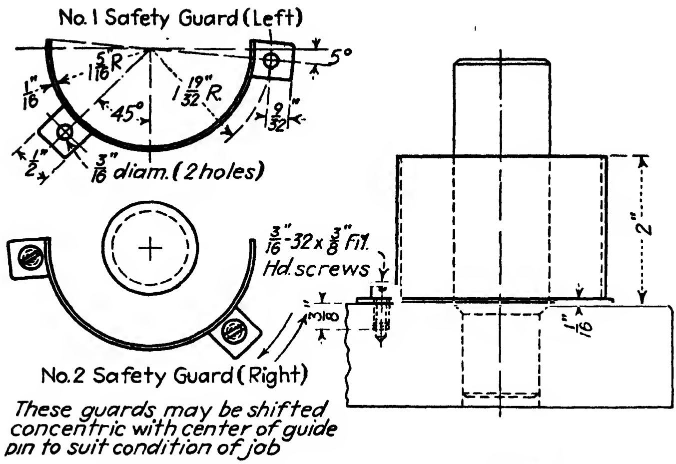


FIG. 61.—N.C.R. safety guards for punch presses.

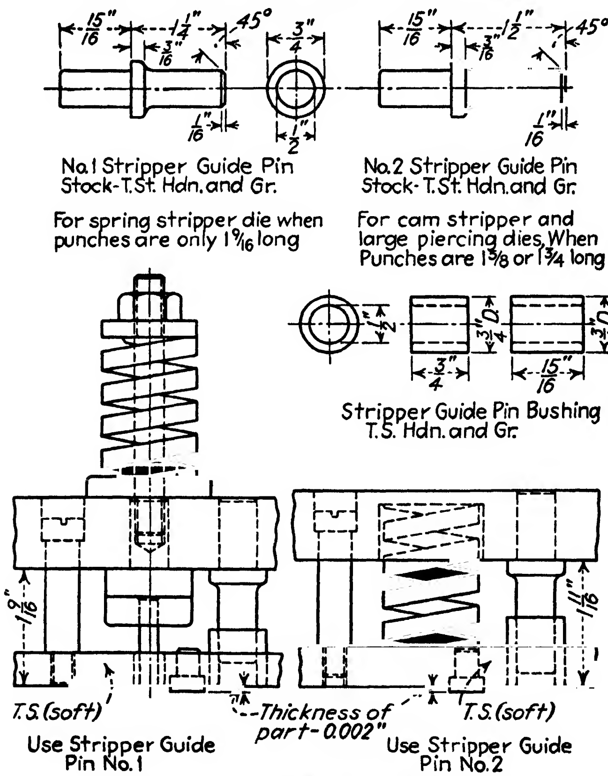
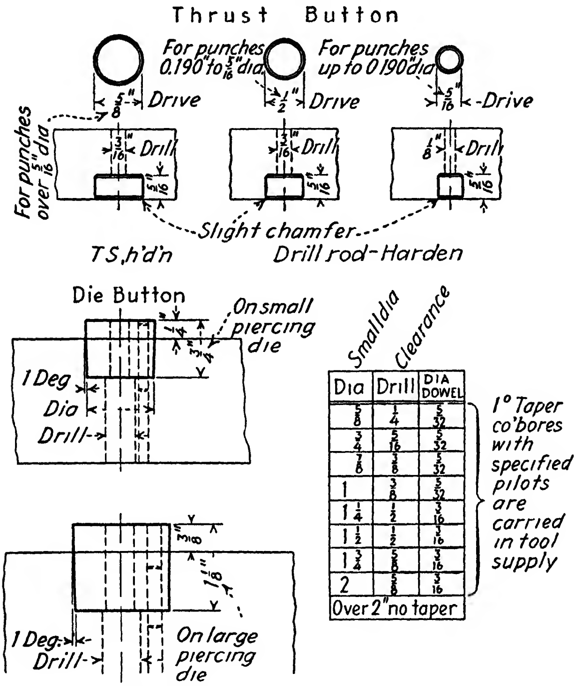


FIG. 62.—N.C.R. types of stripper guide pins.

buttons are also shown in Fig. 63. The buttons are tapered 1 deg. and have a small dowel on one side to insure against turning.

How Jigs Are Standardized in One Shop.—Many shops are beginning to appreciate the savings possible from standardizing jig and fixture parts. The practice of the Heald Machine Co. is an excellent example of what can be done in this line, especially



Dia	Drill	Dia Dowel
5/8	1/4	5/32
3/4	5/16	5/32
7/8	3/8	5/32
1	3/8	5/32
1 1/4	1/2	3/16
1 1/2	1/2	3/16
1 3/4	5/8	3/16
2	5/8	3/16
Over 2" no taper		

FIG. 63.—Thrust buttons for backing up small punches.

as their problems are typical of those found in many plants doing accurate work in limited quantities. Many of the jigs are used to locate drilled or bored holes in precise relation to plane surfaces or to other holes in the same part or in a mating part. The following principles are followed in designing jigs:

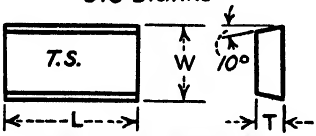
Standard clamping knuckles are used to give the work two-way location.

Automatic locking latches hold the lids of box jigs.

Use press-fit bushings instead of slip bushings wherever possible.

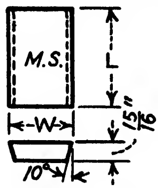
Table 30.—Die Blanks, Punch Holders, Stripper Plates, and Sub-plates

Die Blanks



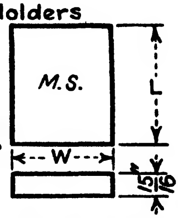
Width	Length	Thickn's
3½	4½	1¼
4	5	1¼
4	6	1¼
4	5	1½
5	6	1½
5	9	1½
7	To suit	1½
8	To suit	1¾
9	To suit	1¾
10	To suit	1¾

Punch Holders



(Bevel edge)

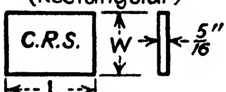
Width	Length
2¾	5
2¾	6
2¾	7
2¾	7½
2¾	10
2¾	11



(Square edge)

Width	Length
5	6
5	8
5	10
5	11
6	8
8	9½

Stripper Plates
(Rectangular)

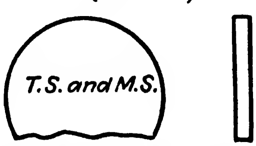


Stripper plates over 8" wide are made of boiler plate

Width	Length
3	4½
3½	5
3½	6
3½	7
3½	8
4½	6

Width	Length
4½	7
4½	8
4½	9
5½	6
5½	7

(Round)



T.S. for piercing die

Diam.	Thickn's
3½	7/16
4	7/16
4½	7/16
5	7/16

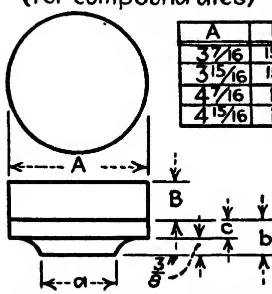
Left soft

M.S. for compound die

Diam.	Thickn's
3½	5/16
4	5/16
4½	5/16
5	5/16

Case harden

Sub Plates and Die Blocks
(For compound dies)



A	B
3 7/16	15/16
3 15/16	15/16
4 7/16	1⅛
4 15/16	1⅛

Sub-Plate and Die Block Assembly

Outside Diam.
3 7/16
3 5/16
4 7/16
4 5/16

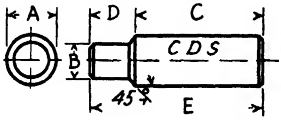
For parts longer than 2 inches, use rectangular block

A	a	b	c
3 7/16	1 15/16	3/4	3/8
3 15/16	2 7/16	3/4	3/8
4 7/16	2 15/16	3/4	3/8
4 15/16	3 7/16	7/8	½

Die block H.S.S.

In many cases bored and drilled parts are located from three plane surfaces, usually at right angles to each other Usually the bottom of the jig takes care of the base of the piece, while two

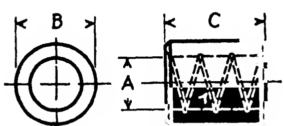
TABLE 31 —GUIDE PINS



A	B	C	D	E
1 1/4	1	4 1/2	15/16	5 7/16
1 1/4	1	5	15/16	5 15/16
1 1/4	1	5	1 1/8	6 1/8
1 1/4	1	6	1 1/8	7 1/8
1 1/4	1	5	1 7/8	6 7/8
1 1/4	1	6	1 7/8	7 7/8
1 3/4	1 3/8	5	1 7/8	6 7/8
1 3/4	1 3/8	6	1 7/8	7 7/8
1 3/4	1 3/8	7	2 1/8	9 1/8
1 1/4	1	2 3/4	1	3 3/4
1 1/4	1	3 1/4	1 1/4	4 1/2

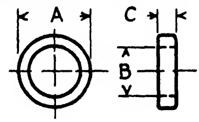
Guide pins under 1/2 – dr r – hd and gr Guide pins up to 1" – t s – hd and gr Guide pins 1" and over – m s – carb – hd – gr

TABLE 32 —GUIDE-PIN BUSHINGS



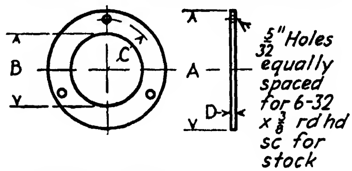
A	B	C
1 1/4	1 3/4	1 7/8
1 3/4	2 5/8	2 1/4

TABLE 33 —FELT WASHERS



A	B	C
1 3/4	1 1/4	3/8
2 5/8	1 3/4	3/8

TABLE 34 —WASHER RETAINERS



A	B	C	D	Retainer No
2 1/2	1 5/16	1 1/16	0038	2
3 5/8	1 13/16	1 9/16	1/8	3
1/4" Holes (3) 1/4 –20 x 2				

locating strips fix the positions of the other two planes In this type of jig it is important that the work be seated quickly and accurately against these strips

The locking knuckle, as shown in Fig 64, locates the work in both planes at once, and as the device is self-equalizing the same

force is applied in each plane. It is simple to use and has many applications, while the action is rapid and positive. The knobs actuating the knuckles have been standardized, as shown in Table 35. These are made in lots and kept in stock for use with any jigs that may require them.

The self-locking latch, shown in detail in Table 36, is a great timesaver, as it locks the lid as soon as it is dropped in place. It is easily released by a light push when the work is done. Fixed bushings eliminate loose parts that may be lost and also prevent the possibility of getting the wrong bushing in place. This is especially valuable where there are several holes of nearly the

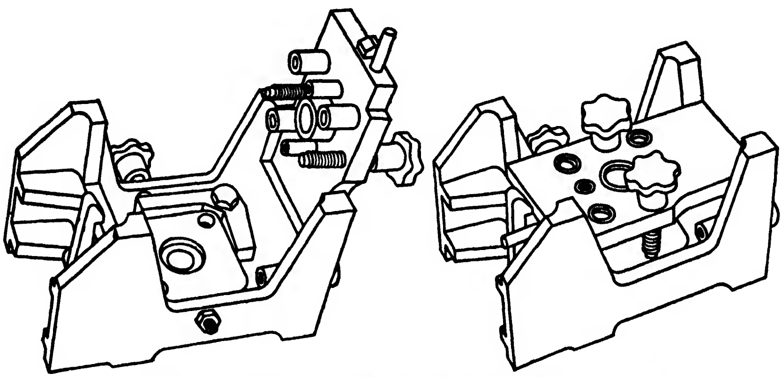


Fig. 64.—Locking knuckles, latches, and fixed bushings.

same size, close together. For reaming and tapping, the lid of the jig is raised out of the way.

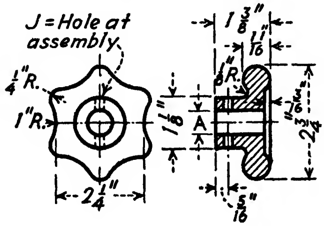
Two views of such a jig are seen in Fig. 64. It will be noted that the locating points are locked, adjustable screws. These are useful when there is an appreciable variation in castings. While seldom needed in small work, they are very useful on larger castings.

Tables 35 and 36 give details and dimensions of hand knobs and latches as well as of screws for the knobs and of locking pins. These are all tabulated and will be found very convenient in many shops.

Die Sets.—Although the actual designing and making of the dies themselves are not in the field of the jig and fixture designer, the die sets, or what was formerly called the subpress die, frequently come in his department. The die sets have been

largely standardized as to dimensions and capacity. They are usually made with two or four guide pins, arranged in different

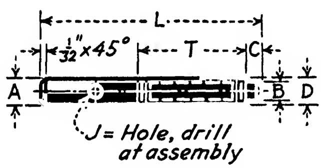
TABLE 35.—HAND KNOBS AND SCREWS



Hand Knobs

Material, cast iron; finish hole and end of hub; remove all sharp corners; mark with number

A	J	Patt. No.
0.500	0.1855	R-2618
½-13	none	



Screws For Knobs

Material, steel No. 2 (screw stock); remove all sharp corners; stamp number on end; case harden point (cyanide)

All threads are U.S. std. R.H.

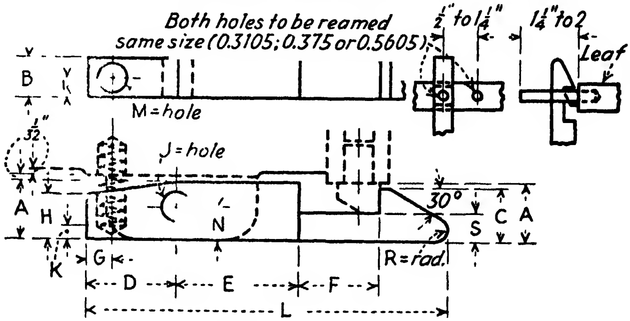
D	A	B	C	L	T	Stock
¼-20	¼	11/64	3/16	2½	1¼	¼ dia. x 2 9/16 long
"	"	"	"	2⅞	1⅝	" 2 15/16 "
"	"	"	"	3¼	2	" 3 5/16 "
"	"	"	"	3⅝	2⅝	" 3 11/16 "
"	"	"	"	4	2¾	" 4 1/16 "
"	"	"	"	4⅜	3⅛	" 4 7/16 "
⅜-16	⅜	9/32	¼	2¼	1⅜	⅜ dia. x 2 5/16 long
"	"	"	"	3	1¾	" 3 1/16 "
"	"	"	"	3½	2¼	" 3 9/16 "
"	"	"	"	4	2¾	" 4 1/16 "
"	"	"	"	4½	3¼	" 4 9/16 "
"	"	"	"	5	3¾	" 5 1/16 "
"	"	"	"	5½	4¼	" 5 9/16 "
"	"	"	"	6	4¾	" 6 1/16 "

ways to suit the work in hand. Some shops have standard sizes of bases and upper plates, designed to suit the average run of

work. Parts are kept in stock so that die sets can be easily made up as wanted.

The illustrations in Figs. 65 and 66 show 16 forms of die sets from which the designer can choose those best suited to his needs.

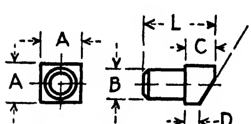
TABLE 36.—COVER LATCHES AND LOCKING PINS



Latches for Covers

Material: Cold rolled steel. Mark with number-case harden (cyanide)

A	B	C	D	E	F	G	H	J	K	L	M	N	R	S	Stock
$\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{8}$	0.251	$\frac{3}{16}$	$3\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{32}$	$\frac{1}{4}$	$\frac{3}{8} \times \frac{1}{2} \times 3\frac{1}{4}$
$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{2}$	1	$\frac{5}{16}$	$\frac{9}{16}$	0.376	$\frac{1}{4}$	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{5}{32}$	$\frac{3}{8}$	$\frac{1}{2} \times \frac{3}{4} \times 4\frac{9}{16}$
1	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{5}{8}$	$2\frac{1}{8}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{11}{16}$	0.501	$\frac{5}{16}$	$6\frac{5}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{5}{8} \times 1 \times 6\frac{3}{8}$



Locking Pin Used with Latch

Material: Ketos, tool steel mark with number harden, Rockwell 50-55

A	B	C	D	L	Stock
$\frac{3}{8}$	0.3125 0.3115	$\frac{1}{4}$	$\frac{1}{16}$	$\frac{5}{8}$	$\frac{3}{8} \times \frac{3}{8} \times \frac{11}{16}$ Long
$\frac{1}{2}$	0.375 0.374	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{7}{8}$	$\frac{1}{2} \times \frac{1}{2} \times \frac{15}{16}$ Long
$\frac{3}{4}$	0.5625 0.5615	$\frac{1}{2}$	$\frac{3}{16}$	$1\frac{1}{4}$	$\frac{3}{4} \times \frac{3}{4} \times 1\frac{5}{16}$ Long

Steel Die Sets.—Among the invasions of steel into fields formerly held by cast iron is that of bases and top plates for die sets. In one large plant where stampings form a large part of the product, all die sets are made to standard dimensions, with both bases and top plates cut from steel plate. These are high-grade boiler plate and vary from $\frac{1}{2}$ in. in thickness for small

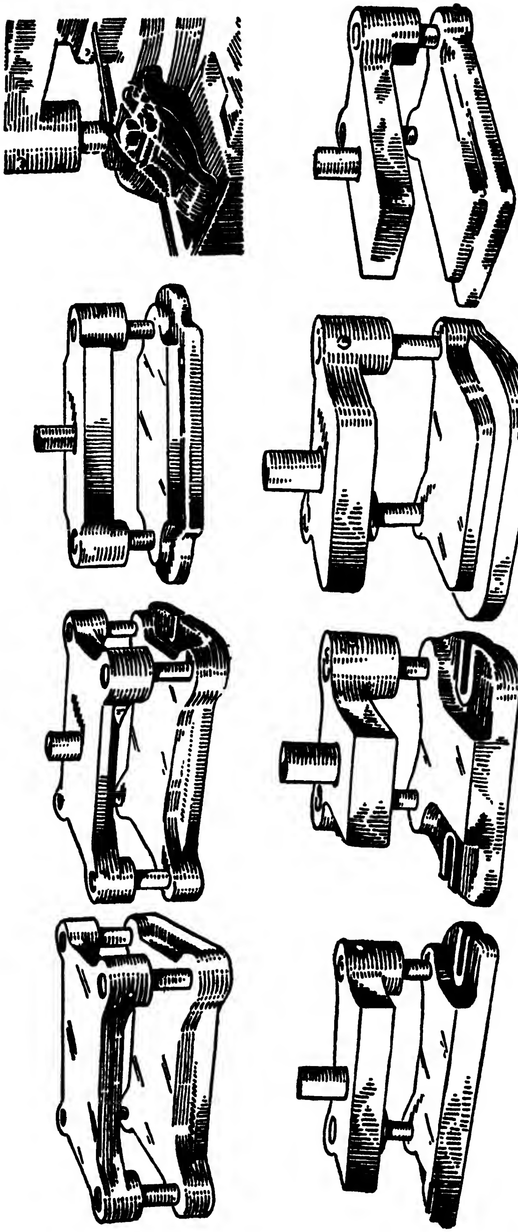


FIG. 65.—Typical die sets designed for various purposes.

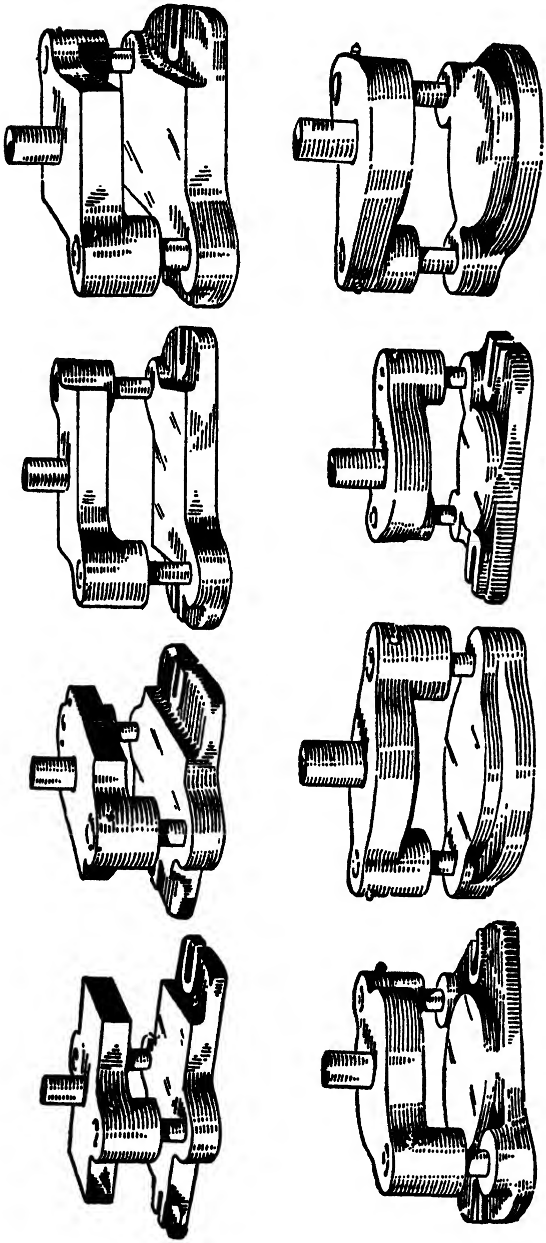
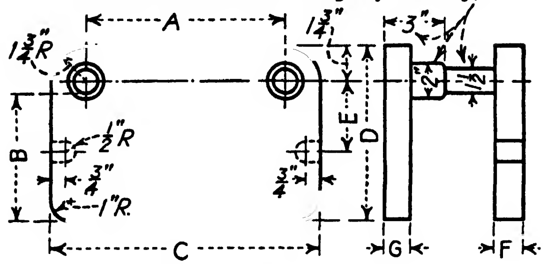


FIG. 66.—Eight more designs of die sets.

Table 37.—Standard Die Sets

These dimensions for Dwg. layout only.



Die space		Dimensions			Thick.		Die space		Dimensions			Thick.	
A	B	C	D	E			A	B	C	D	E		
6	3⅞	9½	6⅜	2⅛	F	1½							
					G	1¼							
10	3⅞	13½	6⅜	2⅛	F	1½	10	6⅞	13½	9⅜	3¾	F	1½
					G	1¼						G	1¼
							14	6⅞	17½	9⅜	3¾	F	2
												G	1½
6	4⅞	9½	7⅜	2¾	F	1½	18	6⅞	21½	9⅜	3¾	F	2
					G	1¼						G	1¾
10	4⅞	13½	7⅜	2¾	F	1½							
					G	1¼							
14	4⅞	17½	7⅜	2¾	F	2	14	7⅞	17½	10⅜	4¼	F	2¼
					G	1½						G	2
							18	7⅞	21½	10⅜	4¼	F	2¼
												G	2
6	5⅞	9½	8⅜	3⅛	F	1½							
					G	1¼							
10	5⅞	13½	8⅜	3⅛	F	1½	18	9⅞	21½	12⅜	5¼	F	2¼
					G	1¼						G	2
14	5⅞	17½	8⅜	3⅛	F	2							
					G	1½							
18	5⅞	21½	8⅜	3⅛	F	2							
					G	1¾							

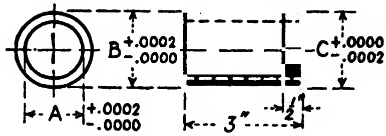
Special Sets in the Following Thickness

Die shoe	1¼	1½	1¾	2	2¼	2½
Punch holder	1¼	1½	1¾	2	2¼	2½

die sets to 2 and 3 in. for those of larger sizes. One set of standards is shown in Table 37.

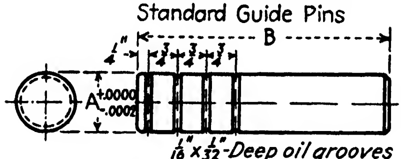
These die-set plates are cut from large sheets with a gas flame, using one of the special machines in which the cutting flame is guided by a templet or pattern. The operator merely follows the outline of the templet, in which the pattern is raised for ease of operation, and the flame cuts the desired form with amazing accuracy. The edge is not only true to form but of such satisfactory finish that no machining is necessary. As will be seen,

TABLE 38.—STANDARD GUIDE BUSHINGS AND PINS



A	B	C
1.2187	1.719	1.7178
1.4687	1.968	1.9668

Standard Guide Pins



A	B	A	B
1.218	5¼	1.468	5¼
1.218	6½	1.468	6½
1.218	7	1.468	7
1.218	8¼	1.468	8¼

the base and top plate are of the same shape, except for the slots at each side for holding the base to the table of the press. Then, too, the top plate is usually thinner than the base.

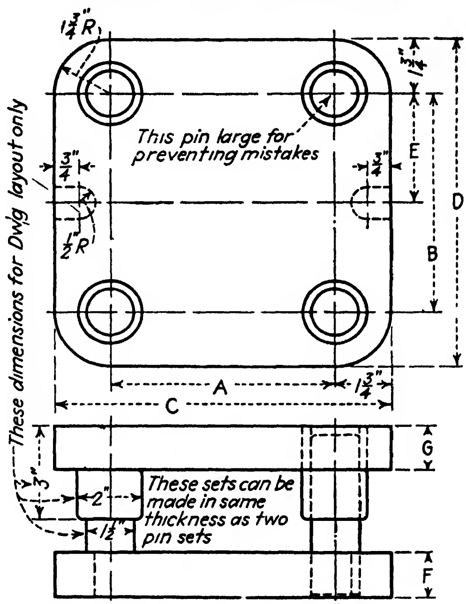
These plates are cut in sufficient quantity to have a supply on which the toolroom can draw as die sets are needed. They go to the toolroom and have both surfaces ground on vertical spindle machines. The pinholes are bored in a simple fixture, under a radial drill. This fixture has holes at several center distances so that any standard die set can be bored by selecting the proper holes and bushings.

Guide bushings and pins have also been standardized. The end of the bushing can be −0.0002 in. for ½ in., while the body of the bushing can be +0.0002 in. but must not be below basic.

The bushing hole can be +0.0002 in. −0.0000. One size of bushings and pins is used on all the die sets shown. Guide-pin dimensions are also given in Table 38.

On very accurate work, such as thin stock where no burr is permissible, a four-pin die set is used, as in Table 39. This employs a square base and top plate and also has one large pin to insure the two parts always going together in the proper

Table 39.—Standard Die Sets



Die-space		Dimensions			Thick.		Die-space		Dimensions			Thick.	
A	B	C	D	E			A	B	C	D	E		
7	7	10½	10½	3½	F	1½	6	6	9½	9½	3	F	1½
					G	1½						G	1½
8	8	11½	11½	4	F	1½						F	
					G	1½						G	

position. The guide pins are forced into the base plates, and the guide bushings in the top plate. With the holes bored square and pins and bushings made to standard dimensions, the top plates move very smoothly on the pins.

Where only a few die sets are needed, and a jig borer is available, the holes can be bored without making such a fixture as has been described. But where die sets are made in quantity, as in this case, the boring fixture is economical from every point of view.

necessary to design the jig so that there would be no danger of chips of iron or dust or dirt entering the tapered bushings, which would prevent the pin from seating itself properly. Then, too, the compound generally used in the drill-press department soon works its way into the bearing which supports the revolving member and when the jig is not in use becomes hard or thick and thus prevents the member from freely turning, which causes considerable trouble in getting the pin to seat itself properly.

Figures 168 and 169 are designs frequently used when there is not a great amount of accuracy required. They are equally good, and in both cases the indexing slots and fingers are operated in a similar manner.

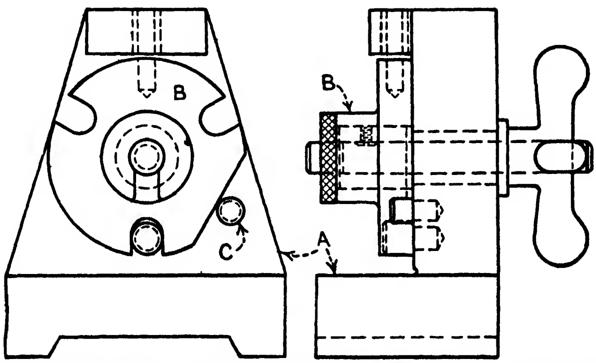


FIG. 171.—Using a pin *C* to insure the work's being put in place properly.

Figure 170 probably originated from those already shown. The bevel index pin, however, is usually more durable than the round index fingers or pins.

MISCELLANEOUS JIG DETAILS

Figure 171 is a good example of applying what is sometimes called in tool designing a "fool pin," but "mistake-proof" would be more descriptive. The illustration shows a drill jig *A* with the part to be drilled *B* properly placed in the jig, and the mistake-proof pin *C* which insures the piece being always placed in the jig in the right position.

It can be readily seen that should this pin be removed, the hole could be drilled in three different points, leaving it to the judgment of the operator to place the piece in correctly. So this pin, or stop, acts as a safety to prevent mistakes.

Figure 172 is a good example of applying a mistake-proof clamp. By its use the same results are obtained as with the pin. The illustration, in like manner, shows the part *A* in a drill jig *B*. The clamp referred to is *C*, which allows the work to go in the jig but one way as well as holds it in place.

In the designing of jigs or fixtures, it frequently happens that methods for allowing the part to enter in the jig but one way are overlooked or left to the judgment of the operator. This is a serious mistake on the part of the designer, as a jig or fixture should be in all cases absolutely mistake-proof.

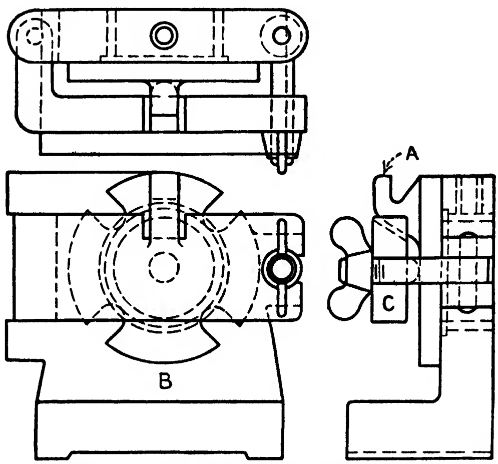


Fig. 172.—A clamp that prevents mistakes.

Methods of Fastening Blocks, Studs, Etc.—There are always more or less small parts, such as those shown in Figs. 173 to 178 inclusive, used in the building of tools, which are bolted or screwed to the jig in order to obtain efficient results for an indefinite period.

These parts may be subject to wear, in which case they are easily replaced. They are frequently used to hold drill bushings, binding screws, etc. In case of a change in the design of the part to be drilled, these extra pieces are used to hold additional drill bushings.

The illustration shows the regular practice of bolting, and attention is called to the important point of properly dowel pinning them in place.

Figure 173 is held by two cap screws and a key, wnile Fig. 174 is held by a dowel pin instead of a key.

Figure 175 is similar to Fig. 174, the only difference being the shape of the part and the fillister-head screw which takes the place of the bolts, or cap screws.

Figure 176 shows a practical way of securing a part to the side of the jig or fixture. The best practice now uses hollow head

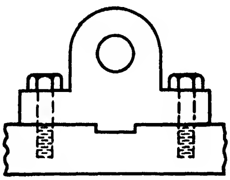


Fig. 173.

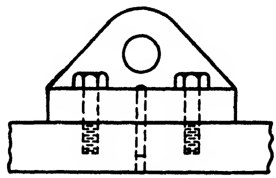


Fig. 174.

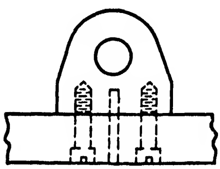


Fig. 175.

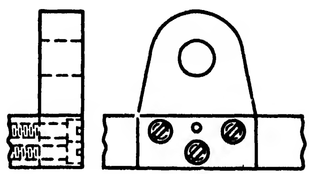


Fig. 176.

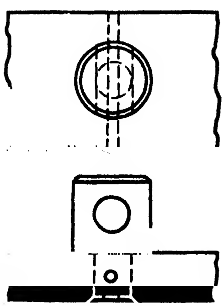


Fig. 177.

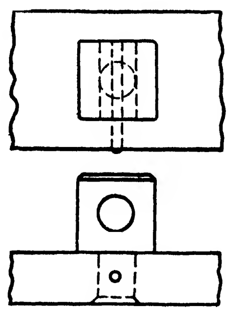


Fig. 178

Figs. 173–178.—Six ways of fastening blocks and studs.

cap screws for work of this kind which adds much to the appearance of fixtures and is better in every way.

Figures 177 and 178 illustrate the use of a round or square stud. The shanks of these studs are turned down and driven in the hole provided for them, after which they are riveted and pinned in place. In some instances, their shanks are threaded, and they are screwed in the jig or fixture.

Jig Profiles.—One of the most difficult things in tool designing is providing means for properly locating the piece in the jig.

This is experienced more where there is a number of irregular bosses and it is more essential to have the holes come in the middle oı these than to have them accurately spaced in relation to one or more holes in the same part. One of the most useful means in a

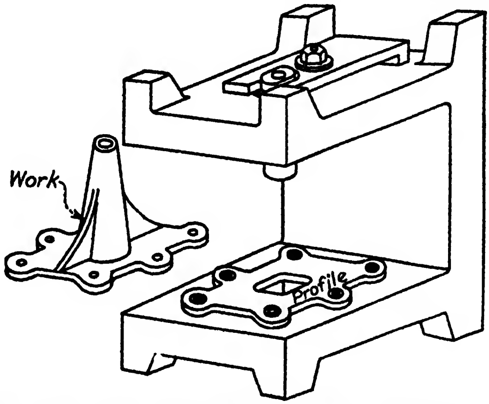


Fig. 179.—A profile outline in the fixture helps to locate the work correctly.

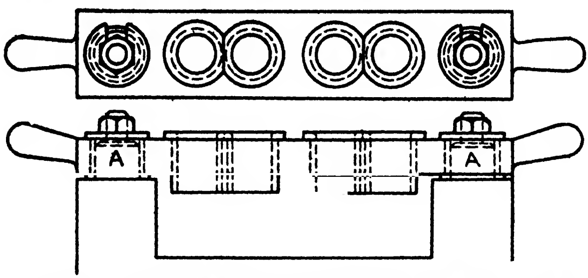


Fig. 180.—Bushings grouped in a plate for easy handling.

case of this kind is what is called a profile on the base of the jig, such as is shown in Fig. 179. This profile consists of a piece of sheet steel about 1/8 in. thick and is cut to correspond to the flange or base of the piece, after which it is screwed as well as dowel pinned on the base of the jig.

In placing the piece in the jig, it is set upon the profile which will readily take care of locating it, after which it is clamped down and drilled.

Figure 180 is a cast-iron plate which contains a number of drill bushings. It is located and held in position by the studs *AA*.

This makes a quick method of removing a number of drill and reamer bushings.

The illustration shows the plate carrying the drill bushing. A second plate, practically the same (except that reamer bushings are used instead of the drill bushings), is not shown.

It is also used when necessary to drill and ream holes which are very close together, as the illustration shows.

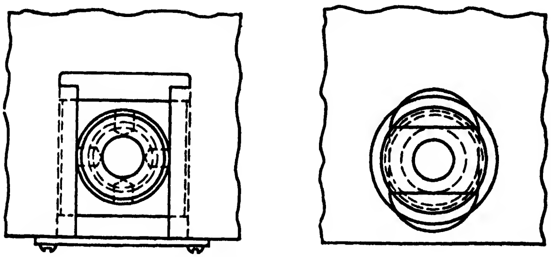


FIG. 181.

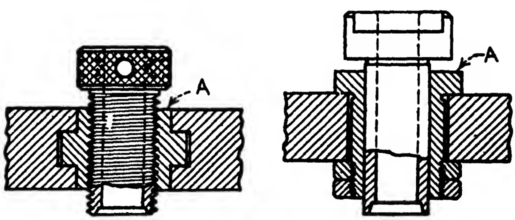


FIG. 182.

FIGS. 181–182.—Different adjustable screw and slip bushings.

Adjustable Screw and Slip Bushings.—In many cases, it is more essential to have the hole drilled in the center of the boss than it is to drill it in any particular relation to other holes in the same part. For this reason, we have what may be called an adjustable screw, or slip bushing, such as is shown in Figs. 181 and 182.

The sliding blocks or bushings *A* carry the drill bushing. These blocks or bushings are made to slide longitudinally in a hole or groove provided for them in the jig.

It is absolutely necessary that they slide freely as well as have no perceptible shake. Where possible, a chip guard should be moved to prevent chips, dirt, etc., from interfering with their movement.

These adjustable bushings are made up in many different ways; the two examples shown are most commonly used.

A variety of thumbscrews and screw handles are shown in Fig. 183.

PROPORTIONS FOR U LUGS AND FOR JIGS AND FIXTURES

Although the sizes of U lugs and other parts of any design must vary to suit conditions and the kind of work involved, it is helpful to know what proportions other designers have found to be useful and satisfactory.

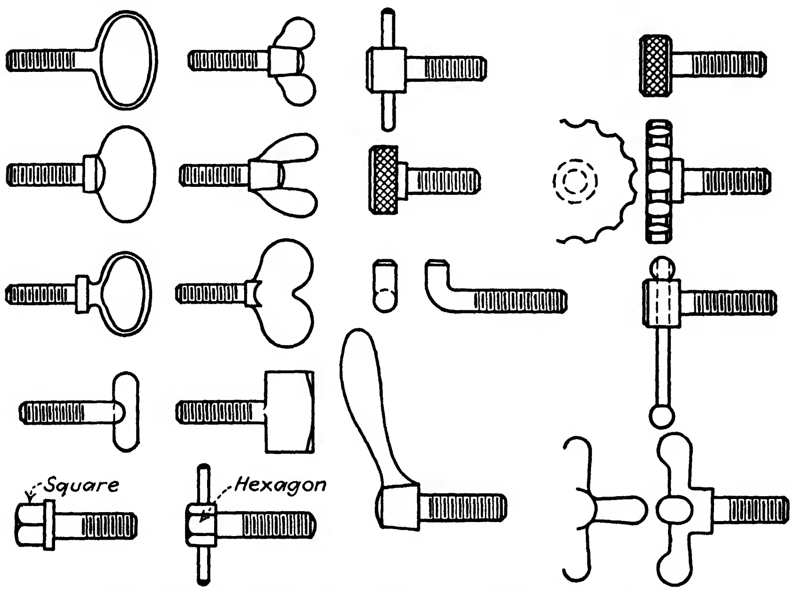


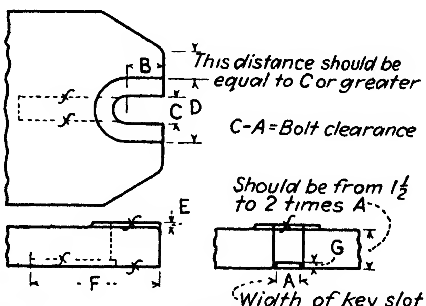
FIG. 183.—A variety of thumbscrews and handles for jigs.

The designs and sizes given in Table 40 show proportions that have been found to work well in numerous instances. This includes both U lugs and keys used in locating the fixtures in the T slots in the tables of milling machines, planes, and other machine tools. It also shows the size of fillister-head screw to use in each size of key.

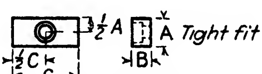
As many fixtures are located by the T slots in the machine tools mentioned, the jig designer should be familiar with the dimensions now used by machine builders. These T slots have now been standardized so that fixtures may be interchanged from one

make of machine to another. The standards adapted are shown in Tables 41 to 48. These include dimensions and tolerances for T slots, cutters used, standard T-head bolts, and T nuts, and for tongues and sets.

TABLE 40.—PROPORTIONS OF U LUGS FOR JIGS AND FIXTURES



Width of slot A	B	C	D	E	F	G	Width of slot A	B	C	D	E	F	G
1/4"	3/8"	5/16"	3/4"	1/16"	1 1/8"	1/16"	5/8"	1"	11/16"	1 1/2"	1/8"	2 3/4"	1/8"
3/8	9/16	7/16	1	3/32	2	3/32	3/4	1 1/8	13/16	1 7/8	1/8	3 1/4	3/16
1/2	3/4	9/16	1 1/4	1/8	2 5/8	1/8	1	1 1/2	1 1/8	2 1/2	1/8	4 1/4	1/4



A	B	C	Size of Screw	A	B	C	Size of Screw
1/4"	3/16"	3/4"	1/8"×40 filister head screw	5/8"	3/8"	1 1/4"	1/4"×20 filister head screw
3/8	1/4	1	3/16"×32 "	3/4	7/16	1 1/2	5/16×18 "
1/2	3/8	1 1/8	1/4"×20 "	1	9/16	2	3/8"×16 "

LAYING OUT A DRILL JIG

Except for the use of metric measurements, toolroom problems are much the same in Europe as in the United States. Here is an interesting problem that Walter Wells ran up against in Soviet Russia.

A circle of 20 holes was to be bored in the body of a jig for the seating of as many drill bushings. The button method of layout, or setup, was to be used. But the job presented some unique problems which had to be overcome by correspondingly unique methods.

The first thing out of the ordinary was the unusual number of buttons to be set up, making for an accumulated error and the consequent "crowding" of the last few buttons to be set, were they to be set consecutively. Then an uneven spacing of the chords was encountered, eliminating the possible use of some sort of spacing device. Furthermore, there is a general awkward-

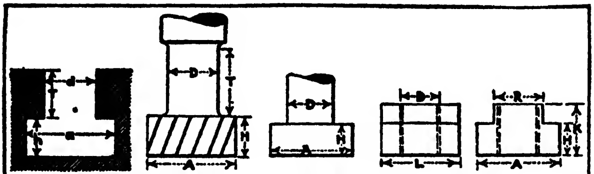


Fig.1 Fig.2 Fig.3 Fig.4

TABLE 41.—DIMENSIONS AND TOLERANCES FOR STANDARD T SLOTS

Diameter of T bolt	Width of throat d	Depth of throat T		Head-space dimensions and tolerances					
				Width			Depth		
		Maximum	Minimum	Maximum, basic	Tolerance, minus	Minimum	Maximum, basic	Tolerance, minus	Minimum
1/4	9/32	3/8	1/8	9/16	0.063	1/2	15/64	0.031	13/64
5/16	11/32	7/16	5/32	21/32	0.063	19/32	17/64	0.031	15/64
3/8	7/16	9/16	7/32	25/32	0.063	23/32	21/64	0.031	19/64
1/2	9/16	11/16	5/16	31/32	0.063	29/32	25/64	0.031	23/64
5/8	11/16	7/8	7/16	1 1/4	0.063	1 3/16	31/64	0.031	29/64
3/4	13/16	1 1/16	9/16	1 15/32	0.094	1 3/8	5/8	0.031	19/32
1	1 1/16	1 1/4	3/4	1 27/32	0.094	1 3/4	53/64	0.047	25/32
1 1/4	1 5/16	1 9/16	1	2 7/32	0.094	2 1/8	1 3/32	0.063	1 1/32
1 1/2	1 9/16	1 15/16	1 1/4	2 21/32	0.094	2 9/16	1 11/32	0.063	1 9/32

ness about the job itself—its large size (outside diameter—about 20 in.) and the presence of an outside rim—which not only prevents the use of a gage to locate inward from the periphery, because of its rough finish, but effectually interferes with the use of micrometers in every direction. Nor is it a typical job for the use of the height gage and indicator exclusively, because the four quadrants of the circle are not symmetrical. It would

TABLE 42.—DIMENSIONS FOR T SLOT CUTTERS

Width of throat		Thickness of cutter *H*		Diameter of cutters *A*		Diameter of neck *D*	Length of neck *T*
Standard	Nominal bolt size	Maximum	Minimum, worn	Maximum	Minimum, worn		
9/32	1/4	15/64	13/64	9/16	1/2	17/64	3/8
11/32	5/16	17/64	15/64	21/32	19/32	21/64	7/16
7/16	3/8	21/64	19/64	25/32	23/32	13/32	9/16
9/16	1/2	25/64	23/64	31/32	29/32	17/32	11/16
11/16	5/8	31/64	29/64	1 1/4	1 3/16	21/32	7/8
13/16	3/4	5/8	19/32	1 15/32	1 3/8	25/32	1 1/16
1 1/16	1	53/64	25/32	1 27/32	1 3/4	1 1/32	1 1/4
1 5/16	1 1/4	1 3/32	1 1/32	2 7/32	2 1/8	1 9/32	1 9/16
1 9/16	1 1/2	1 11/32	1 9/32	2 21/32	2 9/16	1 17/32	1 15/16

TABLE 43.—DIMENSIONS FOR STANDARD T BOLTS

Diameter of T bolt	Threads per inch	Bolt heads dimensions and tolerances						
		Width across flats *A*			Height *H*			
		Maximum, basic	Tolerance, minus	Minimum	Width across corners	Maximum, basic	Tolerance, minus	Minimum
1/4	20	15/32	0.031	7/16	0.663	5/32	0.016	9/64
5/16	18	9/16	0.031	17/32	0.796	3/16	0.016	11/64
3/8	16	11/16	0.031	21/32	0.972	1/4	0.016	15/64
1/2	13	7/8	0.031	27/32	1.238	5/16	0.016	19/64
5/8	11	1 1/8	0.031	1 3/32	1.591	13/32	0.016	25/64
3/4	10	1 5/16	0.031	1 9/32	1.856	17/32	0.031	1/2
1	8	1 11/16	0.031	1 21/32	2.387	11/16	0.031	21/32
1 1/4	7	2 1/16	0.031	2 1/32	2.917	15/16	0.031	29/32
1 1/2	6	2 1/2	0.031	2 15/32	3.536	1 3/16	0.031	1 5/32

TABLE 44.—DIMENSIONS AND TOLERANCES FOR STANDARD T NUTS

Tap for stud *D*		Width of throat T slot	Width of tongue *R*			Width of nut *A*			Height of nut *H*			Total thickness including tongue *K*	Length of nut *L*
Diameter	Threads per inch		Maximum, basic	Tolerance minus	Minimum	Maximum, basic	Tolerance, minus	Minimum	Maximum basic	Tolerance, minus	Minimum		
1/4	20	11/32	0.330	0.010	0.320	9/16	0.031	17/32	3/16	0.016	11/64	9/32	9/16
5/16	18	7/16	0.418	0.010	0.408	11/16	0.031	21/32	1/4	0.016	15/64	3/8	9/16
3/8	16	9/16	0.543	0.010	0.533	7/8	0.031	27/32	5/16	0.016	19/64	17/32	7/8
1/2	13	11/16	0.668	0.010	0.658	1 1/8	0.031	1 3/32	13/32	0.016	25/64	5/8	1 1/8
5/8	11	13/16	0.783	0.010	0.773	1 5/16	0.031	1 9/32	17/32	0.031	1/2	25/32	1 5/16
3/4	10	1 1/16	1.033	0.015	1.018	1 11/16	0.031	1 21/32	11/16	0.031	21/32	1	1 11/16
1	8	1 5/16	1.273	0.015	1.258	2 1/16	0.031	2 1/32	15/16	0.031	29/32	1 5/16	2 1/16
1 1/4	7	1 9/16	1.523	0.015	1.508	2 1/2	0.031	2 15/32	1 3/16	0.031	1 5/32	1 5/8	2 1/2

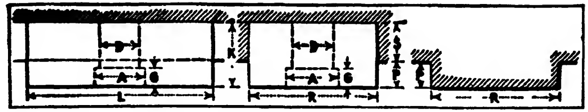


TABLE 45.—INSERTED AND SOLID TONGUES AND SEATS FOR SINGLE WIDTH T SLOTS

Diameter of T bolt	Tongue dimensions			Depth of seat S	Total thickness K	Diameter of screw D	Screw dimensions			Thickness of head G
	Width R	Length L	Projection P				Number of screw	Threads per inch	Diameter of head A	
1/4	9/32	3/8	3/32	1/8	7/32	0.125	5	40	0.196	0.081
5/16	11/32	15/32	1/8	5/32	9/32	0.164	8	32	0.260	0.107
3/8	7/16	9/16	1/8	3/16	5/16	0.190	10	24	0.303	0.124
1/2	9/16	3/4	1/8	7/32	11/32	1/4	..	20	0.375	0.130
5/8	11/16	15/16	1/8	1/4	3/8	1/4	..	20	0.375	0.130
3/4	13/16	1 1/8	5/32	9/32	7/16	5/16	..	18	0.438	0.150
1	1 1/16	1 1/2	7/32	11/32	9/16	3/8	..	16	0.500	0.170
1 1/4	1 5/16	1 7/8	1/4	3/8	5/8	3/8	..	16	0.500	0.170
1 1/2	1 9/16	2 1/4	5/16	7/16	3/4	1/2	..	13	0.625	0.210

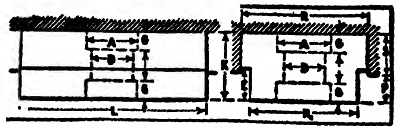


TABLE 46.—DIMENSIONS FOR REVERSIBLE TONGUES AND SEATS FOR TWO SIZES OF T BOLTS

Diameter of T bolt		Tongue dimensions				Depth of seat S	Total thickness including tongue K	Height of shoulder E	Screw dimensions				Thickness of head G
		Width		Length L	Projection P				Diameter of screw D	Number of screw	Threads per inch	Diameter of head A	
Small	Large	R	R										
1/4	5/16	9/32	11/32	15/32	1/8	5/32	9/32	1/8	0.164	8	32	0.260	0.107
5/16	3/8	11/32	7/16	9/16	1/8	3/16	5/16	9/64	0.190	10	24	0.303	0.124
3/8	1/2	7/16	9/16	3/4	1/8	7/32	11/32	5/32	0.250	..	20	0.375	0.130
1/2	5/8	9/16	11/16	15/16	1/8	1/4	3/8	5/32	1/4	..	20	0.375	0.130
5/8	3/4	11/16	13/16	1 1/8	5/32	9/32	7/16	3/16	5/16	..	18	0.438	0.150
3/4	1	13/16	11/16	1 1/2	7/32	11/32	9/16	1/4	3/8	..	16	0.500	0.170
1	1 1/4	1 1/16	15/16	1 7/8	1/4	3/8	5/8	9/32	3/8	..	16	0.500	0.170
1 1/4	1 1/2	15/16	19/16	2 1/4	5/16	7/16	3/4	11/32	1/2	..	13	0.625	0.210

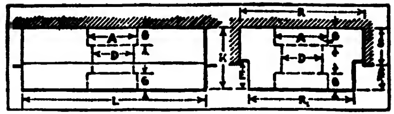


TABLE 47.—DIMENSIONS FOR REVERSIBLE TONGUES AND SEATS FOR T SLOTS OF TWO WIDTHS WITH SAME T BOLT

Diameter of T bolt	Tongue dimensions				Depth of seat S	Total thickness including tongue K	Height of shoulder E	Screw dimensions				
	Width		Length L	Projection P				Diameter of screw D	Number of screw	Threads per inch	Diameter of head A	Thickness of head G
	$R1$	R										
1/4	1/4	9/32	3/8	3/32	1/8	7/32	3/32	0.125	5	40	0.196	0.081
5/16	5/16	11/32	15/32	1/8	5/32	9/32	1/8	0.164	8	32	0.260	0.107
3/8	3/8	7/16	9/16	1/8	3/16	5/16	9/64	0.190	10	24	0.303	0.124
1/2	1/2	9/16	3/4	1/8	7/32	11/32	5/32	1/4	..	20	0.375	0.130
5/8	5/8	11/16	15/16	1/8	1/4	3/8	5/32	1/4	..	20	0.375	0.130
3/4	3/4	13/16	1 1/8	5/32	9/32	7/16	3/16	5/16	..	18	0.438	0.150
1	1	1 1/16	1 1/2	7/32	11/32	9/16	1/4	3/8	..	16	0.500	0.170
1 1/4	1 1/4	1 5/16	1 7/8	1/4	3/8	5/8	9/32	3/8	..	16	0.500	0.170
1 1/2	1 1/2	1 9/16	2 1/4	5/16	7/16	3/4	11/32	1/2	..	13	0.625	0.210

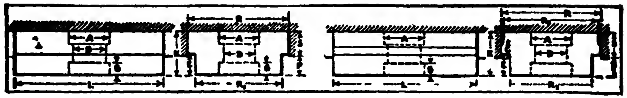


TABLE 48.—DIMENSIONS FOR REVERSIBLE TONGUES FOR TWO WIDTHS OF T SLOTS

Diameter of T bolt		Tongue dimensions						Depth of seat S	Total thickness, including tongue K	Height of shoulder E	Thickness of land G	Screw dimensions				
		Width				Length L	Projection P					Diameter of screw D	Number of screw	Threads per inch	Diameter of head A	Thickness of head G
Small	Large	R1	R	R3	R2											
1/4	5/16	9/32	11/32	5/16	1/4	15/32	1/8	3/16	5/16	1/8	1/16	0.164	8	32	0.260	0.107
5/16	3/8	11/32	7/16	3/8	5/16	9/16	1/8	7/32	11/32	9/64	1/16	0.190	10	24	0.303	0.124
3/8	1/2	7/16	9/16	1/2	3/8	3/4	1/8	1/4	3/8	5/32	1/16	0.250	..	20	0.375	0.130
1/2	5/8	9/16	11/16	5/8	1/2	15/16	1/8	9/32	13/32	5/32	3/32	1/4	..	20	0.375	0.130
5/8	3/4	11/16	13/16	3/4	5/8	1 1/8	5/32	5/16	15/32	3/16	3/32	5/16	..	18	0.438	0.150
3/4	1	13/16	1 1/16	1	3/4	1 1/2	7/32	3/8	19/32	1/4	3/32	3/8	..	16	0.500	0.170
1	1 1/4	1 1/16	1 5/16	1 1/4	1	1 7/8	1/4	7/16	11/16	9/32	1/8	3/8	..	16	0.500	0.170
1 1/4	1 1/2	1 5/16	1 9/16	1 1/2	1 1/4	2 1/4	5/16	1/2	13/16	11/32	1/8	1/2	..	13	0.625	0.210

take too much time to get the readings for the successive resettings from horizontal to the perpendicular.

This jig is designed to drill the screw holes around the face of a large cylinder. The uneven spacing of the chords is explained by the fact that various units, with two holes each and left- and right-hand settings, are to be screwed to the cylinder together with the cap.

To a certain extent, in this case the metric system of measurement will be used. Wherever practical, a rough English approxi-

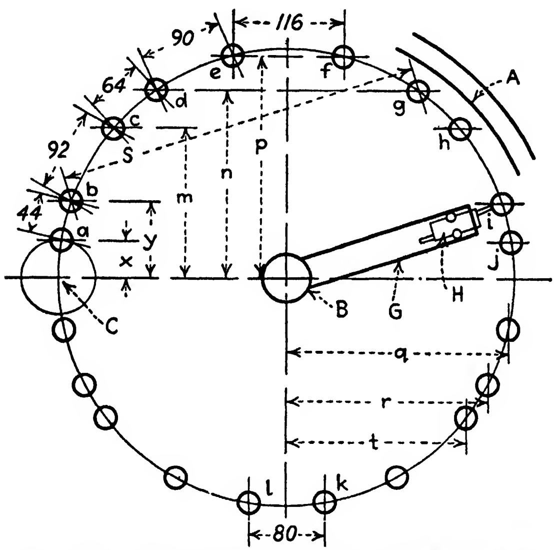


FIG. 184.—Laying out a circle with various spacings

mation will be given; but in dealing with the checkup and tolerance limits a set of Johansson metric-test blocks were used, and the Russian tolerance limits, which are also metric, following throughout. The latter are as follows: 0.02 mm. (0.0008 in.), preferably 0.01 mm. (0.0004 in.), for the button setup; 0.04 mm. (0.0016 in.) for the bored-out hole; and 0.05 mm. (0.002 in.) for the pressed-in drill bushing. The Jo blocks progress by 0.01 mm. from 1 to 1.5 mm. and then on up by halves and integers, the largest block being 100 mm. long (4 in.). Thus, any combination, as in the English set, can be wrung together.

Referring to Fig. 184, chordal dimensions are given metric for convenience. For instance, chord *ab* reads 44 mm. The body

design and clamping devices on the jig are purposely omitted to concentrate attention only on the points under discussion. With this in view, only two physical details are shown, *viz.*, a suggestion of the outside rim, at *A*, which, as stated, interferes with the micrometer readings; and the central plug, which is the registering point for the radial measurements.

Beginning at the left intersection of the center line and working around clockwise, it is obvious that the chord spacings vary. In the next quadrant, the spacings repeat themselves in reverse order (see parallel projection lines). In the third quadrant, there is an entirely different order of spacing, which can be readily seen by comparing the first three buttons here with any three in the preceding quadrants. The fourth quadrant is inversely related to the third. Lastly, observe that chord *ef* is unlike chord *kl* on the opposite end of the vertical center line, thus defeating any attempt to indicate these pairs up horizontally within reasonable time limits.

To solve the problems offered in this job with the least amount of resistance, a combination of checking methods was used all at one time as an alternative to the customary method of shifting the job from horizontal to the perpendicular. Each button was given a final setting before tackling the next one; no return trip was contemplated or, as we shall see by the method to be described, was necessary.

First, the center plug was nicely ground to fit. Then a flat strip of cold-rolled steel, 1/8 by 1 1/4 in., was shaped to fit around the center plug (see *B* and *G*) and cut off somewhat short of the circle line. A bent scriber was attached to this so that the circle line could be scratched on the coppered surface of the jig body, using a height gage to determine the radius line and setting the scriber to it. The chords were laid out with dividers, as nearly as reasonable care could make them. Then all the button locations were scribed to 1/2-in. diameters as sharply as possible. After the holes were drilled and tapped, the burrs were removed with a drill so as not to obliterate the circles, as is many times done with a file. The buttons were then screwed down nearly "home," using the circles as a guide. These precautions save much time on long jobs, such as this.

The Setting.—With the buttons all on, the setting was begun. The strip *G* was fitted with a finger indicator in place of the

scriber, the clamping stud having been removed from underneath. A vernier height gage was used to set the first button *e* according to the dimension *p* (given on the blueprint), attaching thereto a different type indicator. This setting, for all practical purposes, yields the radial distance from the center, so a finger indicator is adjusted so that it reads zero against this button. Or, to be more exact, just 0.01 mm. more was added to the radius than the dimension on the print called for. This was done to prevent the crowding in the chord spacings, which always happens if no such "nursing" within the tolerance limit is allowed. This crowding is probably resultant from a slight leaning of the buttons, causing the gage readings to be taken only over the high spots. The indicator gage is made to traverse the buttons clockwise only, to assure uniform readings.

Button *a* is now first set radially with the special gage. Then the gage is clamped lightly in position, maintaining its zero reading (the design of the jig permitting this), while the vertical setting is accomplished with the height gage and indicator. Using a piece of ⅛-in. brass wire, flattened and rounded out on the end, and a light hammer for tapping, a cross location of a button is rarely disturbed. Button *b* is set the same way, with the added precaution of counterchecking with the Johansson blocks for the intervening chord. Button *c* is skipped for the time being for a reason which will be presently explained. At this point, it must be mentioned that all that applies to the left side of the jig pertains also to the right, so we weave back and forth from *a* to *j* to *i* to *b*.

Now, in an upward progress and passing the 45-deg. mark, it is found that the radial gage begins to serve more as a means of obtaining height than of lateral position. That function being already fulfilled by the regular height gage, other means must be found to set the remaining buttons horizontally. If Fig. 185 is examined, it will be found that, while the gage will register still nicely at the second or even third button, when carried to the fourth and fifth the readings will be too crude; the disparity between the radius and the lateral dimension is too great. In fact, the graduations might mean infinity if carried to the 90-deg.

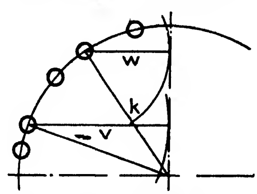


Fig. 185.—Diagram of gage measurements.

mark. So we have to register by other means from a point of which we are certain.

This brings us to the most interesting part of the job. On Fig. 184 is a dimension, marked *s*, diagonally across the upper part of the sketch. This reaches from button *b*, which is positively located in a horizontal direction, to button *g*, which is in need of such location. Before going into the details of this step, it is well to observe here that once we have located button *g* horizontally we can readily get the horizontal location of button *f* by spacing it off with a Jo block. Likewise, buttons *d* and *c* may be located by repeating the same process in the upper left quadrant. This diagonal leap across is a sort of strategic move to get the advantage of the most positive diagonal measurement.

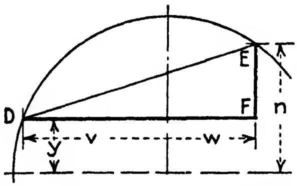


Fig. 186.—How the readings were secured.

The setting was done with a 1-meter vernier caliper, which is rigid in its jaws and permits of 0.01-mm. measurements. The reading was secured from the triangle *DEF* in Fig. 186. *EF* is simply dimension *n* minus *y*, while *DF* is the sum of *v* plus *w*. The hypotenuse *DE* therefore gives the reading. The calipers were set at the reading plus the diameter of one button. Bringing the height gage and indicator into play to get the vertical setting, the button is moved along to what feels like a setting within the jaws of the caliper. Then it is screwed tight. The caliper is set at 0.01 mm. less, and the setting is checked to see if the caliper fails to clear the button; then at 0.01 mm. more to make certain that the vernier does clear. As a further check, the special gage was swung around to this position to see whether it would read the required zero.

Once a quadrant was set, all the other quadrants were set on the same principle. The upper left quadrant used the same dimensions as the upper right; but for the two lower ones, different dimensions had to be figured out. The entire job did not take long to set up. All except two of the dimensions were given on the drawing, and these two required but simple arithmetic to compute. After boring out, the checkup was as simple as the original setup.

CHAPTER IV

WELDED, CAST-IRON, AND LIGHT METAL FIXTURES

Because of the changes that are taking place in machine design, the problems of the tool designer and of the toolroom that makes the jigs and fixtures that he designs are greater than ever before, in the opinion of L. E. Fuller, tool engineer of the Brown & Sharpe Mfg. Co. Since designs do not run for so long a time as formerly but are changing frequently as mechanical, hydraulic, and electrical controls are improved, the application of machine tools is almost limitless. Because of these frequent changes, the tools used in making these machines, such as jigs, fixtures,

FIG 187.—Where cast iron is best.

and gages, must pay for themselves in a shorter time than formerly.

To meet this condition, welded tools are unquestionably the answer, and they have come to the fore at the right time, because they can be made at less cost and in a shorter time than has been possible heretofore. The interchangeability of clamps, brackets, and small parts is much more easily accomplished with the gas torch and arc welder. Clamps that were formerly forged are now built up by arc-welding blocks, thus eliminating nearly all machining in the toolroom.

Cast-iron Tools.—There are some cases where a pattern (Fig. 187.) and a casting would be the choice for a tool. These are chosen for the special surface plate shown, because the design of this tool does not lend itself to arc welding, and also because use of a cast-iron surface is better practice for scraping.

Figure 188 shows a finish-boring fixture. This fixture is made of cast iron because of the extreme accuracy required to be maintained over a long period of time. The center distance of the tool holes remains more stable than with boiler plate arc-welded together for the type of tool.

FIG 188.—Another place where cast iron seemed best

FIG 189.—Pattern and core box for cast-iron angle plate

Where standard-stock cast-iron jigs made from the same pattern can be used to advantage, this method of construction should be the choice instead of gas or arc welding.

Welded Tools.—The economies to be made with arc-welded special tools are many. In studying the thousands of both types that have been made, we find a substantial saving in favor of the arc-welded tools. These savings can be readily under-

stood by a comparison of similar tools. Figure 189 is a simple cast-iron angle block for which a core box and pattern are required. Figure 190 is an arc-welded angle block of similar size and design, which was made of plates welded together without any pattern or core box. The welded block is lighter and has sufficient strength to compare with cast iron.

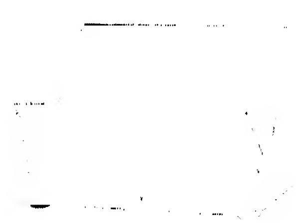


FIG. 190.—Similar angle of welded plate.

Greater savings can be made (up to 30 per cent in some cases) in the manufacturing cost of jigs and fixtures, compared with similar cast-iron tools; the conventional type of cast-iron jigs is ignored, and a tool produced from stock steel shapes (as shown in Fig. 191) which are satisfactory for many parts.

The extent of surface areas to be machined in the toolroom should be considered, as it takes about 5 per cent longer to machine the same area of steel over cast iron. This may be offset, however, by reducing these areas to a minimum.

FIG. 191.—Where a welded fixture saved money.

The equipment required for economical production of welded tools up to the point of machining is as follows: First, a gas torch suspended on an arm (Fig. 192). This torch is used for cutting long, straight, and angular plates. In addition, a suitable arc welder (Fig 193) is required. This is used in conjunction with a metal grounded table. The jig on this table is first tack-welded and later completed with a bead weld of proper strength for the

tool. This equipment is obviously small in comparison with the machinery required for making patterns, core boxes, and molds.

Good, accurate tools can be made by welding and, if normalized, will keep their shape and last as long as required. Surfaces subject to excessive wear should be hard-surfaced with hardened blocks or by welding on stellite rod. The feet of jigs so treated can be surface ground for finish.

FIG. 192.—Suspended gas torch for fixture work.

All of the tools that have been described were made from drawings. However, the one shown in Fig 194 took just a few hours to make. This fixture for milling a special part was put on the machine ready for work the same day that it was called for. It was made from a rough sketch with a few figures. This would have been impossible if a pattern, mold, and casting had been necessary.

There does not seem to be any limit to the type of tools that can be welded, except in a very few cases, some of which have been mentioned. If one will take advantage of the opportunities

offered by the arc-welded tools, he has gone a long way toward solving his present and future tooling problems.

FIG. 193.—The arc welder used in this work.

FIG. 194.—Milling fixture ready for work the same day.

Money Saved by Welded Jigs and Fixtures.—In many cases, welding can reduce the cost of such equipment and can produce

the tools in much less time, as there is no waiting for patterns and castings. Fixtures can be built up from small parts and save much machining, especially if the designer can forget about cast-fixture methods and design especially for welding. One large shop estimates a saving up to 30 per cent in some of its

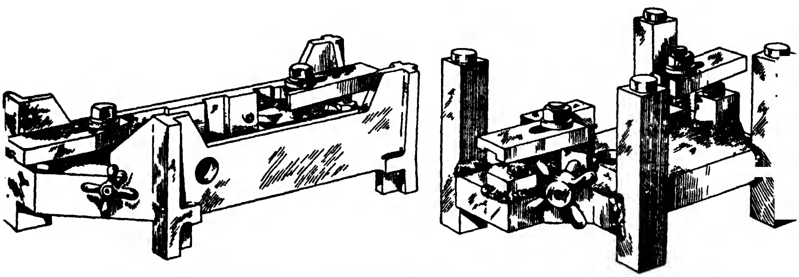


FIG. 195.—Difference in design between cast and welded fixture.

fixture work. There are places, however, where the cast type of fixture is still best adapted; enthusiasm for a new method should not blind one to the use of the old where advisable.

A few examples of welded fixtures are shown in Figs. 195 to 198. These vary widely in size and use Figure 195 gives a direct comparison of two fixtures for similar pieces. The use of

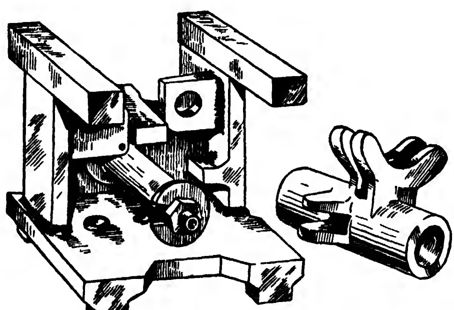


FIG 196.—Where welding saved 30 per cent.

square steel for corner pieces, especially when the ends have hardened-steel insets for bearing surfaces, has many applications.

Three other examples, from the Warner & Swasey shops, show substantial savings by the use of welded fixtures In Fig. 196, the piece drilled and the fixture welded up for the operation are shown. Welding of this fixture saved 30 per cent over the usual

method. The milling fixture in Fig. 197 was made at a saving of 13 per cent over cast iron; and in Fig. 198, which is for boring the piece shown, the saving was 20 per cent.

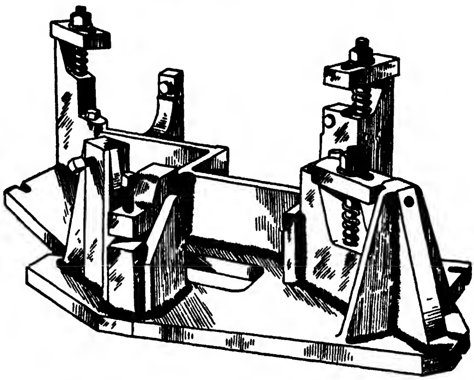


FIG. 197.—This saved 13 per cent over cast iron.

Efficient Jigs Fabricated from Steel.—The following examples by Frank Hartley of welded jigs show how steel plates can be cut and welded into fixtures without waiting for the pattern-maker or the foundry. Wherever practicable, the cheapest jigs are usually those built up from commercial steel members,

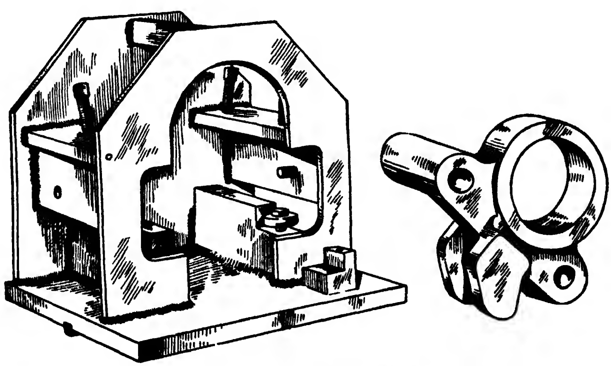


FIG. 198.—Here the saving was 20 per cent.

and there is considerable satisfaction in being able to say, "They didn't cost much; we built them out of a few pieces of cold-rolled steel." The accompanying illustrations are of jigs of such a type.

In the jig in Fig. 199, two blind holes are to be drilled in the segment A. The entire locating is done by the pivoted member

B. It centers the work radially in the V slot *C* and locates it sidewise therein. An additional function of member *B* is to clamp the work by forcing its flat surface against the underside of the bushing plate *D* by means of screw *F*. In placing and removing the work, the free end of member *B* must be dropped down considerably, the amount being indicated at *H*. The pivoted block *J*, against which screw *F* abuts, is swung outward from under the screw, permitting the free end of member *B* to be dropped to the base of the jig.

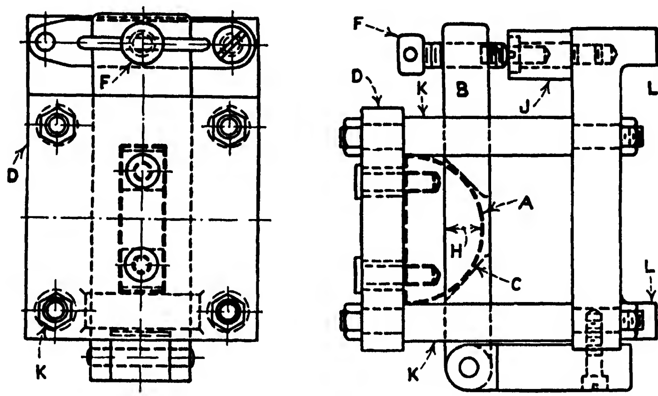


FIG. 199.—Work is centered and clamped by one motion.

Bushing plate *D* is held by the four shouldered posts *K*, and the underside of the jig base is cut away so as to leave two resting spots, or feet, at *L*. When another segment is put in the jig, pivoted member *B* is lifted up, block *J* is swung inward under the point of screw *F*, and the screw is tightened to clamp the work against the underside of the bushing plate. The clamping action rocks the segment so that its flat surface is brought square against the underside of the bushing plate.

A jig of rather unusual design is illustrated in Fig. 200. The work to be drilled and reamed is a ribbed casting of semicircular shape. The various bushings are of reamer size, and the first operation consists in spotting the holes with a short drill of full size and then drilling through the work with a smaller drill, leaving enough stock for reaming with a machine reamer.

The primary object is to locate the work from its central point, since the outer ends are to be machined to shape after

drilling and reaming have been completed. The work *A* is held against the central block *B* by the inverted V block *C*, which is attached to the sliding bar *D*, engaging a slot in the work. The work is clamped by two knurled thumbscrews *F* and bears on the clearance bushings *H*. The sliding bar is held down by plate *J* and passes through a slot in the underside of the central block *B*. It is operated by screw *K*, which is threaded into block *L*. Plate *M* carries a bushing through which the central hole *N* is drilled and reamed, and the two end plates *O* have bushings at *P* to guide the drill and the reamer for the end holes.

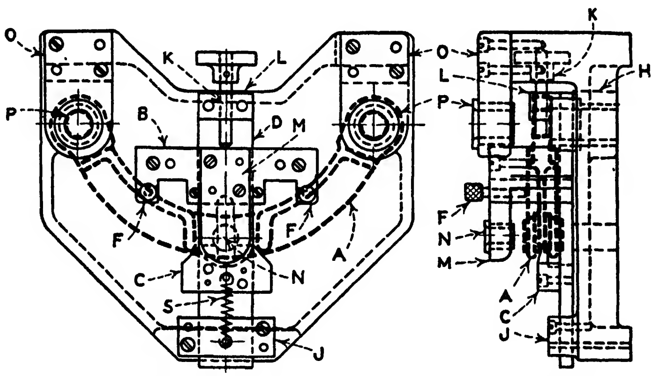


FIG. 200.—An inverted V block locates by a center slot.

To remove the work, the knurled thumbscrews *F* are backed off, screw *K* is loosened, and the spring *S* pulls back the sliding bar and the inverted V block a sufficient distance for clearance. The work can then be lifted up at the center and removed by sliding it from under the bushing plates *O*. In placing the work, it is slid under the bushing plates from the front, and the inverted V block is brought into engagement with the slot in the center by screw *K*, centering the work against the central block. Knurled thumbscrews *F* are then screwed down on the rib.

In providing the type of clamping device in the jig illustrated in Fig. 201, consideration was given to the fact that the work *A* had to be clear of the tongues *B* in the base of the jig to permit it to be placed and removed. The illustration shows the overhanging portion of a large jig in which the unit shown is one of two used as a locating means. The work has a long, finished slot and is located by the finished surfaces *C* and *D*. It is

clamped in place by the screw *F* in the hinged bushing plate *H*, which is free to swing about pin *J* as a center and is held in a horizontal plane, so that the bushings are at a right angle to the work, by the collar *K* on the pivoted screw *L* contacting with a boss in the base of the jig. The collar is pinned to the pivoted

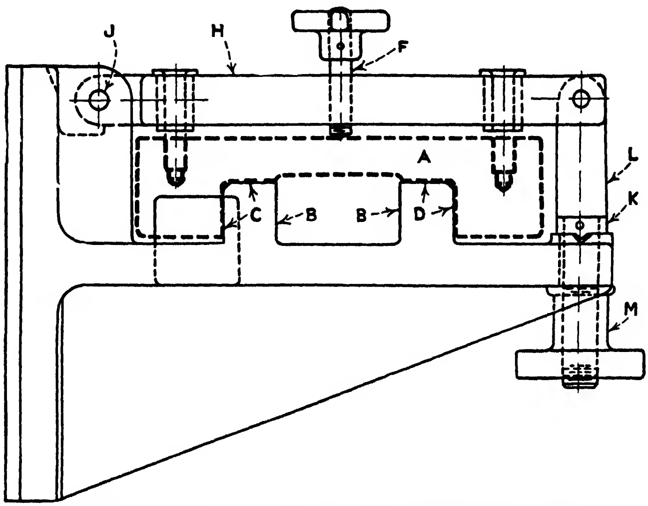


Fig. 201.—Located by tongues and clamped by screws.

screw, and an inverted V projection engages a V notch in the boss and holds the screw in a vertical position. When the knurled nut *M* is backed off, the pivoted screw can be swung clear of the base, and it and the bushing plate can be swung clear of the work.

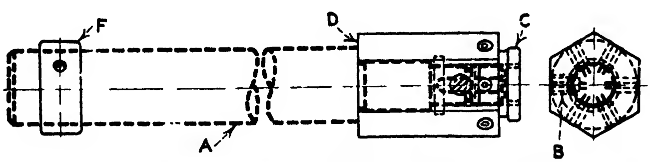


Fig. 202.—Six holes are drilled halfway through to meet in center.

Simplicity marks the design of the jig in Fig. 202, the function of which is to hold and index the end of the shaft *A* while six holes are being drilled for a cotter pin. Ordinarily, three holes would be drilled clear through the threaded end of the shaft, using but three bushings. However, it was found to be more

satisfactory to drill six holes meeting at the center; besides, a shorter drill could be used.

The body of the jig is hexagon in shape and is rolled over on successive faces in drilling the holes. It is bored to fit the threaded end of the shaft on which it is located by the reduced point of screw *B* engaging a keyway. The knurled nut *C* engages the end threads of the shaft and holds the jig against the shoulder *D*. In addition to the jig itself, the collar *F* is placed on the shaft and acts as an outer resting point to support the shaft so that it will be aligned with the hexagon faces of the jig.

Light-weight Jigs and Fixtures.—There are many operations where the weight of the jig or fixture is an important item, as the time and effort of handling may seriously affect the cost of the operation. In cases where weight must be considered, the use of aluminum and the still lighter metal magnesium is becoming more common. Although the first cost of using these metals may be higher than if the fixtures were made of cast iron, the saving in handling time frequently compensates for the added cost.

A suitably built jig must be easy to handle so as to reduce to a minimum the time necessary for exchanging the work and consequently the idle time of the machine. Since many automobile parts that have to be machined are bulky, *e.g.*, crankcases, gear cases, and cylinder blocks, the fixtures for machining these parts are of large size. This is a serious disadvantage, as their weight makes it difficult to mount and to dismount them as well as to operate the movable parts of the fixtures quickly. The increased load on the machine and the greater power consumption of mechanically operated fixtures are objectionable. Finally, it must be remembered that the operator has to use more time and energy in handling a heavy fixture, and this increases the operating time per piece.

For these reasons, the weight of fixtures should be kept as low as possible. The use of magnesium-alloy castings lends itself particularly toward accomplishing this result. Leading automobile manufacturers in Europe have realized the usefulness of magnesium alloy in the building of fixtures and during the last few years have been using it wherever a reduction of weight was required.

It is, of course, necessary to take into consideration the characteristic properties of magnesium alloy when using it in a mechanical design, and no excessive demands should be made upon it with respect to wear. Such parts as drill bushings, guide rails, stops, and the like should be protected with steel; and if the

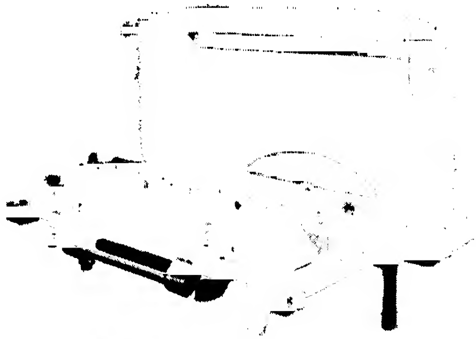


Fig. 203—Magnesium-alloy fixture is light to handle.

fixture is to undergo considerable handling in use, the corners should be steel reinforced

The accompanying illustrations show a number of drill jigs where magnesium alloy has been successfully used. Figure 203

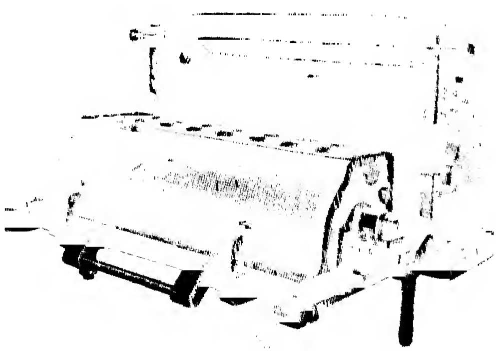


Fig 204.—Same fixture with work in place.

shows a jig for drilling 134 holes in an eight-cylinder magnesium-alloy crankcase. The hinged lid, which is moved during the operation, is a magnesium casting, and the drill bushings, stops, and guide rails are made of steel or covered with steel plates The hinged lid is about 35 in. long and 22 in. wide. The light

weight is evident when one realizes that one man is easily able to open and close the magnesium lid even with the work in place. Figures 204 and 205 show the jig with the work in place, in the

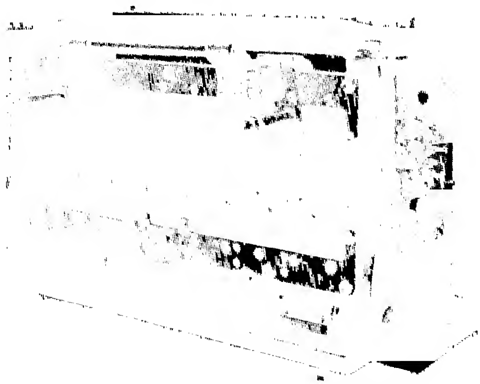


FIG 205 —Fixture closed for drilling

open and closed position. Figures 206 and 207 illustrate other fixtures developed on the same principle.

Occasionally, the objection is raised that the use of magnesium alloy may represent an increase in the cost of the fixtures One

FIG 206 —Another magnesium-alloy fixture.

answer to this objection is that the cost of machining magnesium parts is low, thus tending to offset a higher cost of raw material. The extent to which this difference in cost is offset depends on the

amount of machining to be done on the part in question. In some cases, however, it will not be possible to avoid an additional outlay for fixtures made of magnesium as compared with those

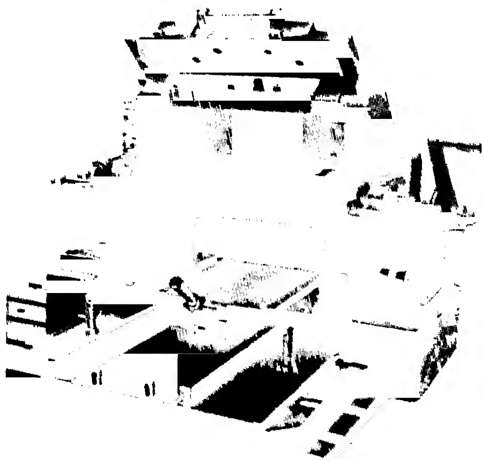


FIG. 207.—A more complicated fixture.

of steel. Notwithstanding a possible increase in first cost when using magnesium castings, they will, in many applications, be found advantageous and to lead to savings which in a relatively short time more than offset the additional first cost.

Section 2

DETAILS IN FIXTURE DESIGN

CHAPTER V

LOCATING SCHEMES FOR DRILL JIGS AND FIXTURES

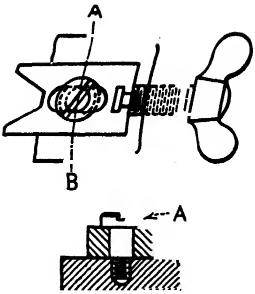
There is no one best way to center or locate work in a jig or fixture. The method to be selected depends primarily on the piece that is to be machined. In many cases, some form of V is used to advantage, and a number of modifications of the V method are shown in Figs. 1 to 13. On some work, all operations are worked from one end, letting whatever inequalities there may be come at the other end. In still other cases, it is necessary to equalize the variations between the two ends, such a method being shown in Fig. 12, in which the piece is held between two V's but equalized by the use of a right- and left-hand screw *A*, which is held centrally by the collar *B*. Various adaptations of the V method of locating work are shown herewith. The plans shown give a variety of ways in which this can be done and allow the selection of the one that the designer considers best for any particular case.

One of the most useful means employed in jig construction for locating or centering the part to be drilled is the V, its construction varying to suit conditions. It is usually operated by means of a screw with a double or triple thread.

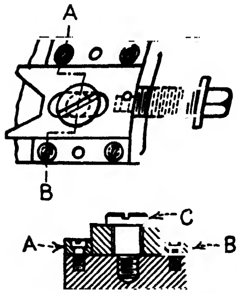
Figure 1 shows a simple construction that is generally used on very small jigs. The V is held down by means of the screw *A* and is also guided by this screw, which is flattened on both sides to fit the slot in V. As shown, the end of the screw also acts as a guide.

Figure 2 is an improved design, being guided by the two gibs *A* and *B*. The V is held down in the same manner as in Fig. 1 by means of the screw *C*. This design is also used in small-jig construction.

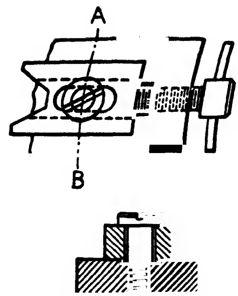
A Cheaper Form.—Figure 3 is practically the same as Fig. 2 except it is a little cheaper to make. It is held down the same way as Fig. 1 but is guided by a tongue instead of the gibs. There is a slot cut in the body of the jig in which this tongue slides.



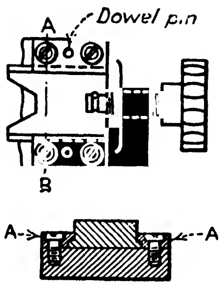
Section A-B
FIG. 1.



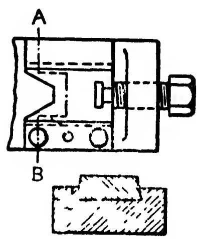
Section A-B
FIG. 2.



Section A-B
FIG. 3.



Section A-B
FIG. 4.



Section A-B
FIG. 5.

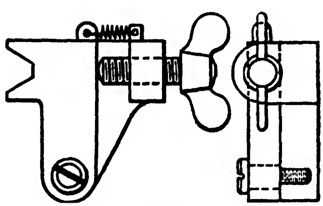


FIG. 6.

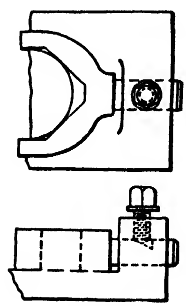


FIG. 7.

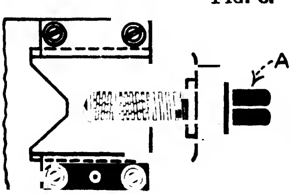


FIG. 8.

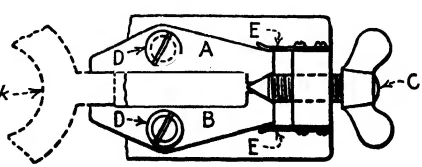


FIG. 9.

FIGS. 1–9.—Methods of locating work in jigs with V blocks and a clamp.

Figure 4 is really the standard form of design for constructing these V's, as it is strong and accurate. The gibs *AA* should be dowel pinned after being located and should be made of steel. In some instances, they are hardened and ground but generally left soft, and the V hardened.

Figure 5 is similar to Fig. 4 except in the design of the gibs, which are dovetailed. This style is more often used in large drill jigs and is, of course, more expensive than any of the others shown, but it has advantages over the others in the way of accuracy and wearing qualities.

Figure 6 is another form of V which is often used when the design of the jig calls for a limited amount of room, being particularly useful in such cases.

Used on Large Jigs.—Figure 7 is a satisfactory way of making a V for locating large bosses, etc. In this design, the V has only a limited amount of movement. It is not very popular and is used mostly on large jigs.

Figure 8 is similar to Fig. 4 and is shown only to give the designer or toolmaker another method of operating a V. The screw *A* is threaded into the block and held by the two collars shown.

Figure 9 consists of two fingers *A* and *B* which are operated by means of a screw *C*. These fingers swing on the screws *D* and are brought back to their original position by means of springs *EE*. This is another design which can be used to advantage when there is only a limited amount of room in the jig.

Figures 10 and 11 show two styles of locating V's that are held down in similar ways but are operated somewhat differently. In the first case, the back end of the V block acts as the nut, the screw not having any end movement. In the second, the screw works through the cross bar and is held in the front end of the V. The gib in both cases acts as a guide for the V and support for the screw.

In Fig. 12 are shown two V's operated by a screw *A* which has a right- and left-hand thread. The flange *B* in the center of this screw works in a slot which holds it in a central position. The two V's are guided in a slot provided for them in the jig and are held down in the same manner as in Fig. 1.

It will be observed that each of the forms shown, as representative of locating devices, possesses some advantages for special purposes, and each will be found useful in certain places.

The term "V block" includes a wide variety of forms but is confined to the use of two surfaces in contact with the work. A number of designs and modifications are shown in Fig. 13. These include plain V's of different forms and adjustable locating

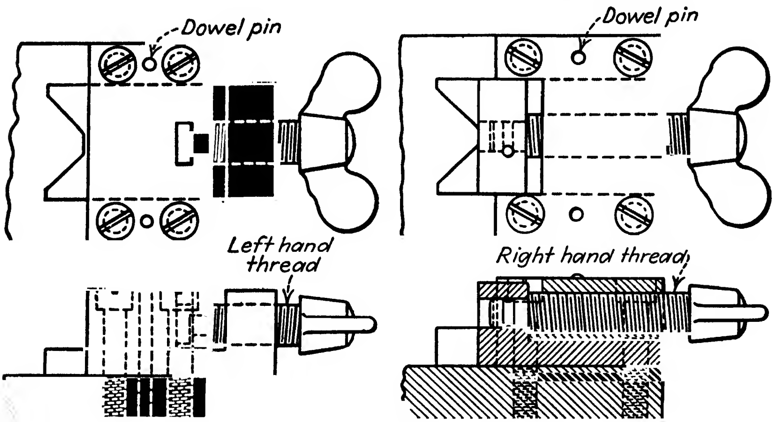


Fig. 10. Fig. 11.

Figs. 10–11.—Two ways of making V-block clamps.

surfaces of varying types. The designer must select the one best suited to his needs.

Stationary or Adjustable Stops.—Probably 90 per cent of the drill jigs designed and made have some form of stops. They may be stationary or adjustable. These stops, or, as they are

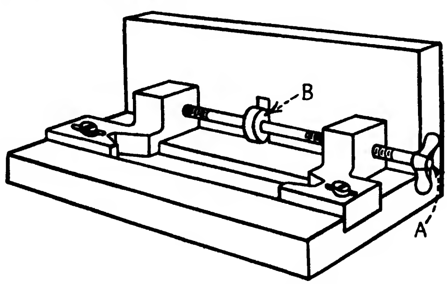


Fig. 12.—Two V blocks on a right- and left-hand screw.

sometimes called, locating points, are used for properly locating the piece in the jig so that the holes will when drilled be in the right position. Figures 14, 15, and 16 are permanent or stationary stops; and Figs. 17 and 18, adjustable stops that can be locked in position.

It is always good practice to make these stops stationary whenever possible, as the adjustable ones very often work loose and result in spoiled work. They also furnish a good excuse for the operator who was careless in placing the part in the jig. For if

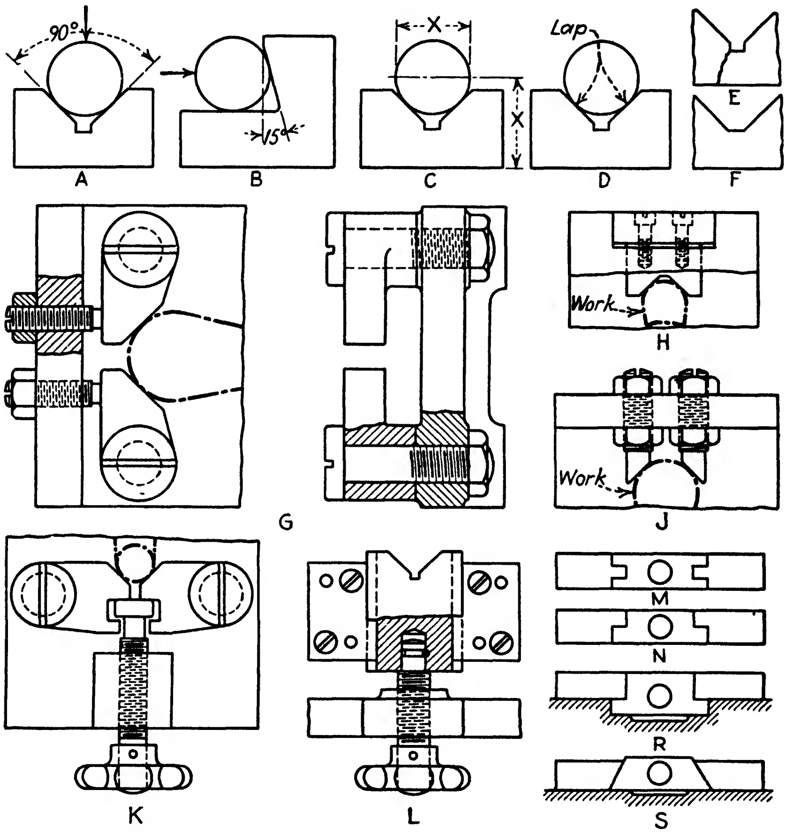


Fig. 13.—Locating work by V blocks and with modifications. *A*, *B* and *C* show how V blocks should be dimensioned. For accurate location the sides should be lapped as at *D*. Unless enough metal is left below clearance space the V may crack under pressure as at *E*. Other views are self-explanatory.

the holes are drilled so that the part is spoiled, he can easily reset the adjustable stops and blame an innocent party. In some cases adjustments are sealed so as to prevent tampering.

Figure 16 is a form of stop screwed and dowel pinned to the jig. This style is made up in many different ways.

They are usually made of tool steel, and hardened. In some cases, they are made of cold-drawn steel and carbonized or case-hardened; and at times they are made part of the jig.

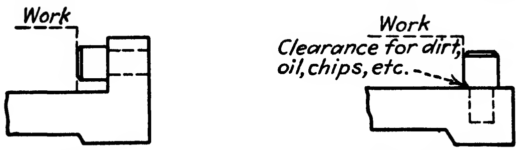


Fig. 14. Fig. 15.

Figs. 14–15.—Two simple fixed, or nonadjustable stops.

In designing all stops similar, be sure to allow clearance for dirt and chips.

Jig for Locating and Locking Work Simultaneously.—For drilling comparatively small parts that are finished to close

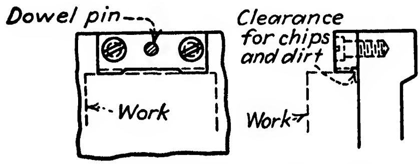


Fig. 16.—Fixed stop with two-point bearing.

dimensions, the jig illustrated in Fig. 19 is convenient and rapid in operation. It consists of the body *A*; the hinged cover *B*, which is also the bushing plate; the locking lever *C*; the locking stud *D*; and the wing nut *E*. The lower end of the locking stud is pivoted to the locking lever, which, in turn, is pivoted to the jig body.

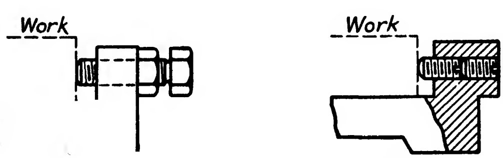


Fig. 17. Fig. 18.

Figs. 17–18.—Adjustable stops that can be locked in position.

The work is located in a nest and is pushed against a ledge in the rear by the toe of the locking lever. When the wing nut is screwed down on the stud and comes in contact with the cover, further screwing raises the locking stud and pushes the toe of the locking lever against the work, forcing it back against the ledge at the rear of the nest. Thus, both the work and the

cover are held tightly. By unscrewing the wing nut a turn or two, the locking stud can be swung down, releasing the work and the cover. The cover can then be raised for admitting or removing the work.

Self-aligning Fixtures.—When several fixtures for machining like parts are mounted in tandem on the machine table, they can be automatically brought into alignment by the construction shown in Fig. 20.

The T slot in the table is beveled as at *A*, and bushings *B* are provided instead of the usual tongues on both ends of the fixtures.

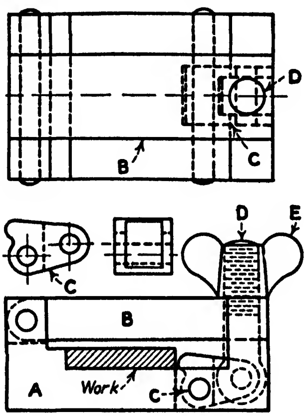


Fig. 19.

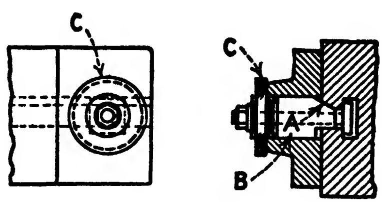


Fig. 20.

Fig. 19.—The toe of the locking lever forces the work back as it is clamped on top.

Fig. 20.—With one side of the tongue beveled the fixture aligns itself.

At one side of the lower ends, the bushings are beveled to fit the beveled side of the T slot, while the opposite sides are straight.

In aligning the fixtures on the table, the nuts on the clamping bolts are tightened slightly, forcing the bushings downward so that the wedging action brings their straight sides against the straight side of the T slot. After the fixtures have been aligned, the collar nuts *C* are screwed down by hand into contact with the fixtures, and the nuts on the clamping bolts are firmly tightened. The object of the collar nuts is to prevent the bushings from being forced down hard enough to injure either them or the T slot.

Jackscrews and Jack Pins.—Figures 21 and 24 are examples of jackscrews which are used for supporting the part to be drilled.

They are also used for taking up the thrust of the drill. Figures 21 and 24 are the most commonly used style of screws. The jackscrews are, however, in many instances, superseded by the jack pins, for the reason that the jackscrews must be adjusted very carefully to prevent springing or distorting the work; and chips, oil, or dirt working into the threads prevent its being operated quickly.

While the jackscrew has its disadvantages, so has the jack pin, but these disadvantages can always be attributed to their design.

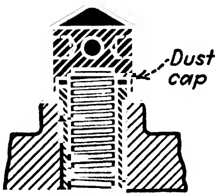


Fig. 21.

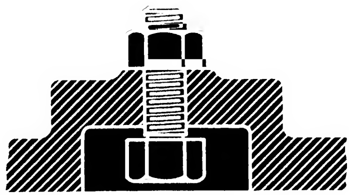


Fig. 22.

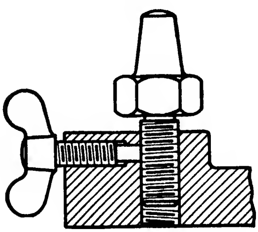


Fig. 23.

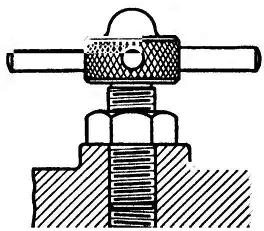


Fig. 24.

Figs. 21–24.—Four simple forms of jackscrews.

A number of illustrations showing different methods of making them will be found in Figs. 25 to 32 inclusive. It is unnecessary to explain the operation of all of them, as they speak for themselves, but a word of caution to the designer or maker is essential.

Figure 25 is not protected from chips, powdered metal, or dirt entering the sides of the pin. This will, therefore, be apt to get out of order soon, and the pin stick in the hole provided for it.

Figure 26 is protected from the chips, dirt, etc., by means of a cap. It is operated by a spring and held in position by the screw which strikes the tapered part of the pin.

Figure 27 is operated by means of a cone-pointed hardened screw. The illustration shows the screw having a square head,

but in most cases it has a knurled or winged head. This design is apparently correct, but it has some bad features.

The power of a screw is too often misjudged by the designer as well as by the machine operator who is to use the device. Here we have the powerful action of the screw as well as the wedge action of the conical end of the screw against the inclined surface of the plunger pin; therefore very little pressure on the screw is sufficient to spring a good-sized casting several thousandths of an inch.

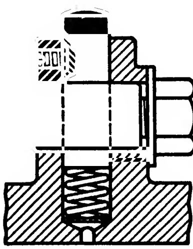


Fig. 25.

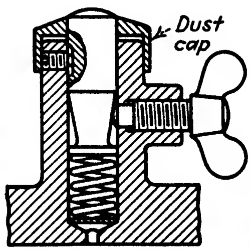


Fig. 26.

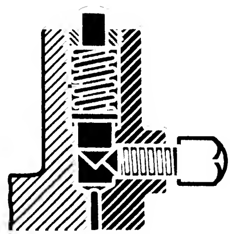


Fig. 27.

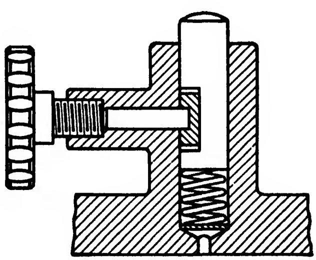


Fig. 28.

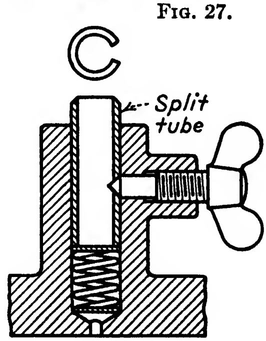


Fig. 29.

Figs. 25–29.—Jackscrews with springs and locking devices.

Figure 30 is similar to Fig. 27, but in this case it is operated by means of a wedge-shaped pin which in turn is operated by a spring. The illustration shows the plunger pin at its extreme height. To loosen the plunger pin, the wedge-shaped pin is pulled out as far as it can be, and the knob turned halfway around. In so doing, the bottom flange of the knob will rest on the head of the small pin *a*, which will hold it out and allow the plunger pin to drop.

Figures 31 and 32 show two ways of operating and holding two plunger pins.

Jackscrews are generally made of cold-drawn steel and casehardened. Jack pins are usually made of tool steel and hardened, although if made of cold-drawn steel and properly casehardened, their wearing quality is very good. Always provide dust caps where possible. A number of forms of jackscrews, some similar

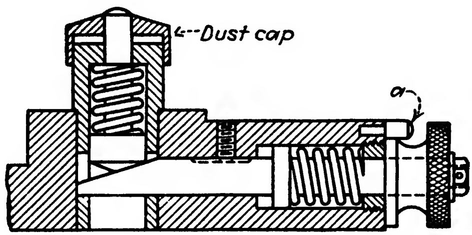


Fig. 30.—Combined wedge and spring action.

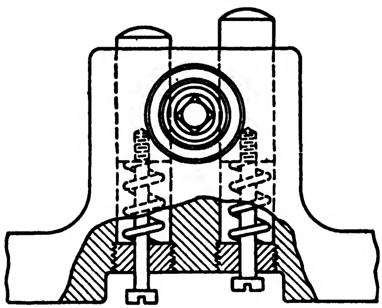


Fig. 31.—A double plunger jack with locking clamp between.

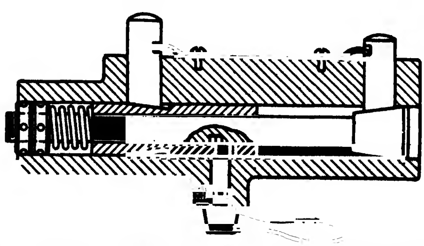


Fig. 32.—Both plungers are controlled by cones beneath.

to those already shown, are given in Fig. 33. From these and the others the designer can select the most suitable for his purpose.

Self-locking Jack.—The device shown in Fig. 34 is a jack which is automatically clamped after it has found its position against the work. The jack pin *A* has a spring beneath it which

lifts it into contact with the work, and there is another spring beneath the washer under the clamp *D*. When the work is in

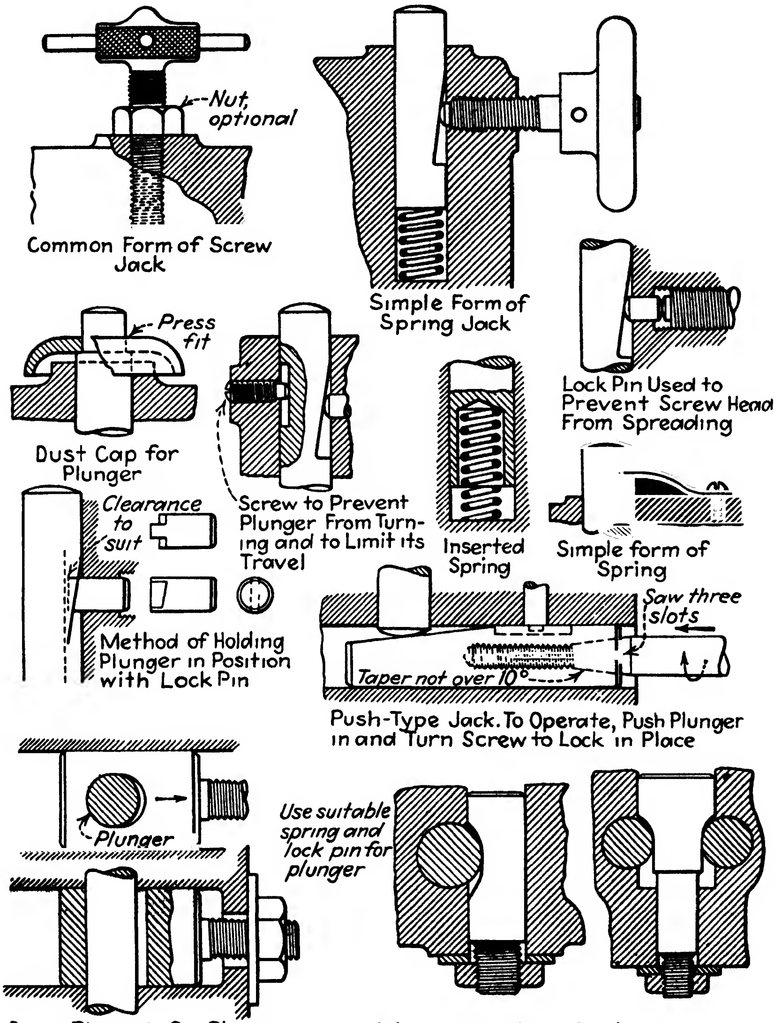


FIG 33.—A collection of jackscrews from various sources.

place, pressure on the clamp *D* forces the pin *C* against pin *B*, which locks the jack pin *A* in position. The bevel on the end of *B* and in the jack pin *A* is 3 deg. Small stop screws in flat

spots on *A* and *B* limit their movement. A hole at the side, behind plunger *C*, permits *B* to be slipped into place in assembling the unit.

The 48 illustrations that follow are from the shop practice of a number of shops and show methods of fastening parts together in a variety of ways, methods of clamping by different means, and devices that are used to lock nuts and other parts. These are divided into four groups and require little, if any, explanation. The first group includes Figs. 35 to 45; the second, Figs. 46 to 58; the third, Figs. 59 to 71; and the last, Figs. 72 to 82. They include the use of locking screws, as in Figs. 35 to 43, with the exception of Fig. 41; which is an offset plate for locating eccentric, or off-center, holes. Figure 39 locks by spreading a split-shaft end, while Fig. 40 expands the split end of the screw as it is screwed into place. In Fig. 44, the cone head spreads two cutters, or centering arms.

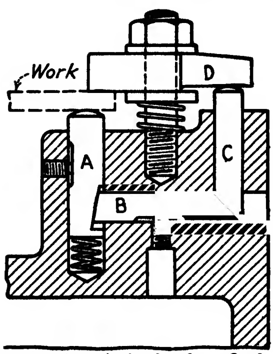


FIG. 34.—A jack that finds its position and locks.

Various clamping methods are shown in the second group (Figs. 46 to 58). Some of these are good for holding cutters in place or parts to be machined, as in Figs. 47 to 49. Figure 50 is an easy method of securing fairly accurate adjustment by the use of two cone-point setscrews.

More clamping devices are seen in Figs. 59 to 71, none of which requires explanation, except perhaps Fig. 60, where a screw is uncovered every 30 deg., the segments, or ears, covering the screws until the opening is reached.

Screw- and pin-locking methods are given in Figs. 72 to 82, varying from the use of a lead washer in Fig. 73 to steel washers with ears to be turned up after the nut is screwed home. These are not complicated to use, and their operation is readily seen.

Multiple Clamping.—It is well known to tool designers that a number of pieces, set up to be machined, can be clamped with a single knob in one operation regardless of variation in size or stiffness of some parts. The objectives sought in designing fixtures incorporating this principle are: (*a*) Every piece should be held with the same pressure; and (*b*) for a given applied pressure,

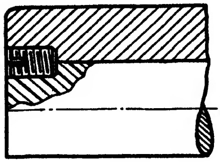


FIG. 35.

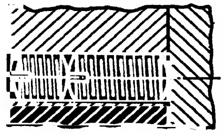


FIG. 36.

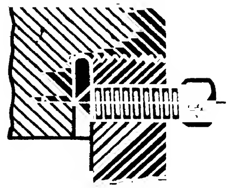


FIG. 37.

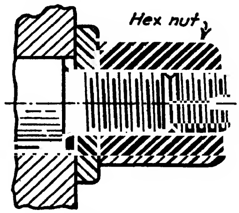


FIG. 38.

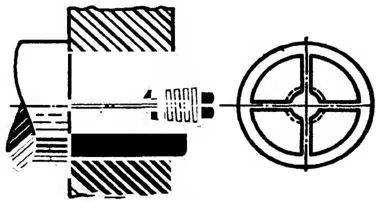


FIG. 39.

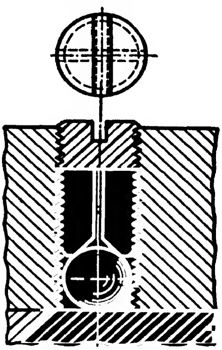


FIG. 40.

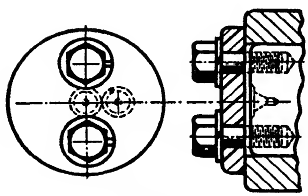


FIG. 41.

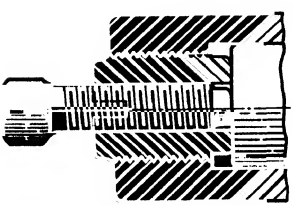


FIG. 42.

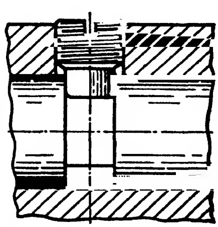


FIG. 43.

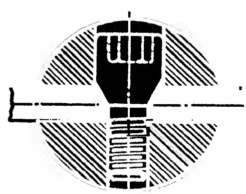


FIG. 44.

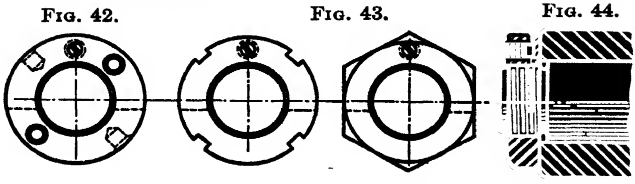


FIG. 45.

FIGS. 35–45.—Methods of using screws for locking parts together.

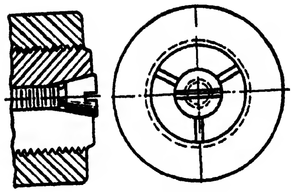


Fig. 46.

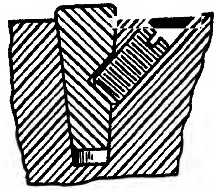


Fig. 47.

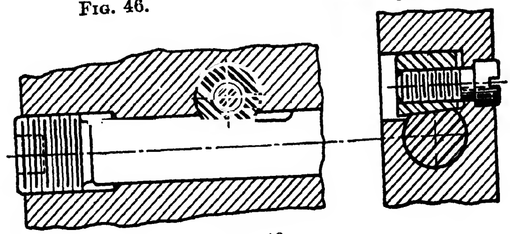


Fig. 48.

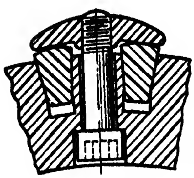


Fig. 49.

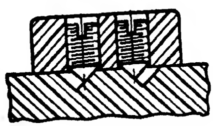


Fig. 50.

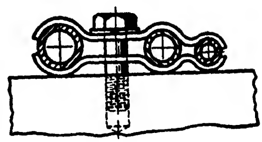


Fig. 51.

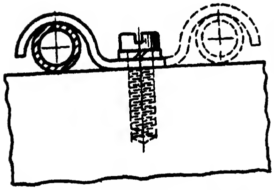


Fig. 52.

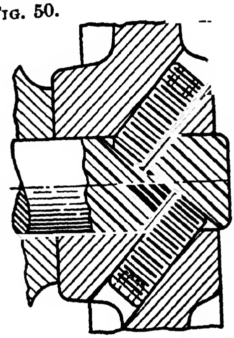


Fig. 53.

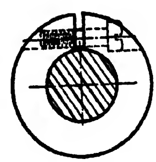


Fig. 54.

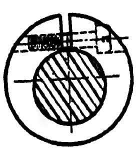


Fig. 55.

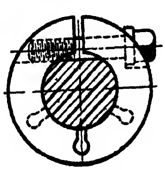


Fig. 56.

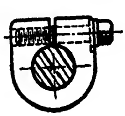


Fig. 57.

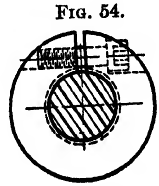


Fig. 58.

Figs. 46–58.—Clamps for holding work in jigs, tools in cutter heads, or other parts.

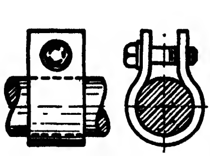


Fig. 59.

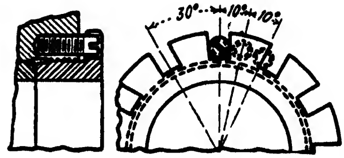


Fig. 60.

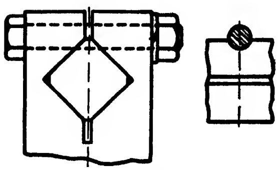


Fig. 61.

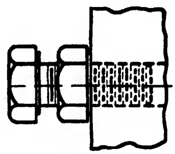


Fig. 62.

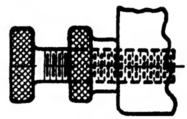


Fig. 63.

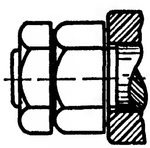


Fig. 64.

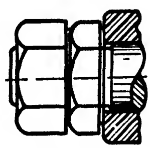


Fig. 65.

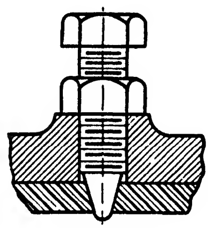


Fig. 66.

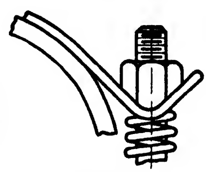


Fig. 67.

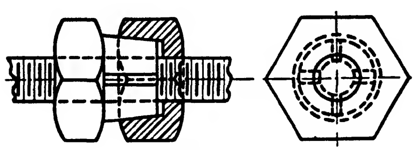


Fig. 68.

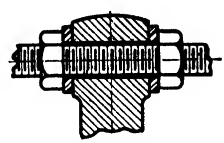


Fig. 69.

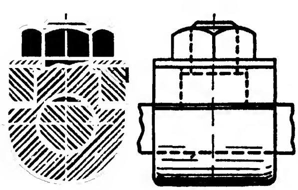


Fig. 70.

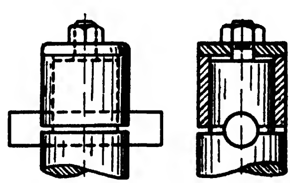


Fig. 71.

Figs. 59–71.—Clamps, lock nuts, expanding collars, and other details.

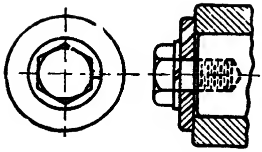


FIG. 72.

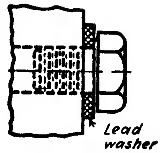


FIG. 73.

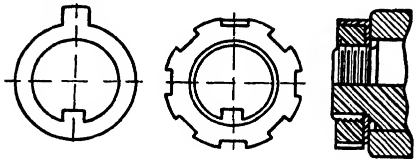


FIG. 74.

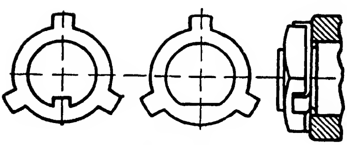


FIG. 75.

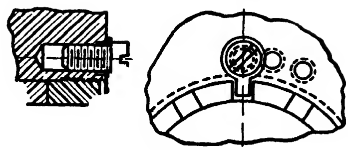


FIG. 76.

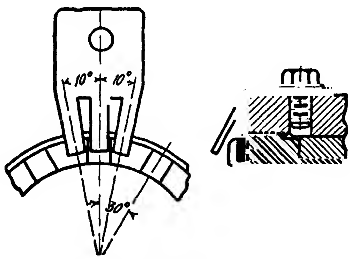


FIG. 77.

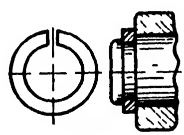


FIG. 78.

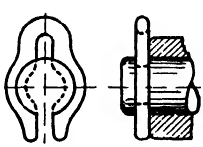


FIG. 79.

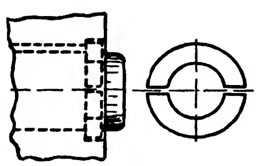


FIG. 80.

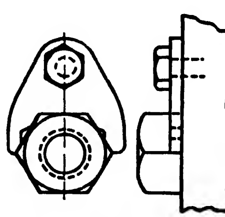


FIG. 81.

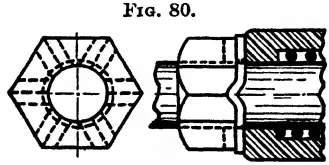


FIG. 82.

FIGS. 72–82.—Other types of locking devices, including nut locks and spring washers.

the cumulative pressure on the parts shall be a maximum. To make the total pressure maximum, x, in all figures, must be minimum in proportion to the length of the main lever. This takes a little figuring, as will be seen.

In the illustrations, the pieces to be clamped are designated by the symbols W_1, W_2, etc. They are located in V blocks and are

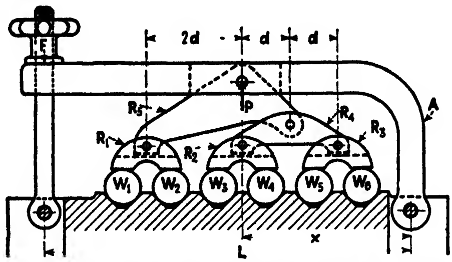


FIG. 83 —Multiple clamps that equalize pressure.

clamped by rockers R_1, R_2, etc. Referring to Fig. 83, rockers R_2 and R_3 are pivoted to the ends of rocker R_4, and rockers R_1 and R_4 are pivoted to the ends of rocker R_5, which in turn is pivoted to the clamping lever A. In clamping all pieces, equilibrium is established by moments of parallel forces. The first two pieces W_1 and W_2 are held by rocker R_1, and it is obvious that

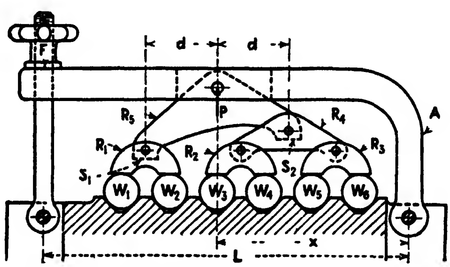


FIG. 84.—Incorrect proportioning of levers.

if both these pieces are to be held with the same amount of pressure, the pivot on rocker R_1 must be equidistant from them.

The equal division of all rockers actually led to the error illustrated in Fig. 84, where rocker R_5 is equally divided, despite the fact that its right-hand end holds down four pieces through rockers R_2 and R_3, while its left-hand end holds down but two pieces through rocker R_1; likewise in Fig. 85, where piece W_2 is

held by one end of both rockers R_1 and R_2, which are proportioned in the ratio of 2:1.

From what has been said it will be seen that levers or rockers can be so proportioned as to get equal pressure on two, three (or a multiple of three), or four pieces. But how about five or seven

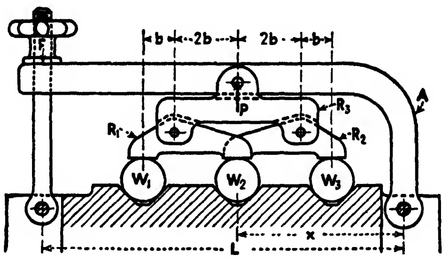


FIG. 85.—Another arrangement of levers.

pieces? An understanding of the theory of moments of parallel forces is necessary for the application of equal pressure on any number of pieces and to obtain maximum pressure thereon.

Referring to Fig. 85, assume that all the pieces held down are made of soft rubber. Under pressure they will flatten out into ellipses with the major axes horizontal, and their cumulative

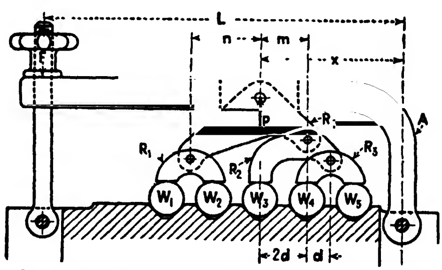


FIG. 86.—Clamps for holding five pieces.

reaction is equal to P. Newton's fundamental law that "action and reaction are equal and opposite" is most simply illustrated by moments of parallel forces. All levers or rockers in the illustrations are beams in the full sense of the word. Let F_1 and F_2 be forces acting on the beam B (Fig. 88). The reactions can then be found by the formula $RL = F_1 \times X_1 + F_2 \times X_2$. Thus, in the other illustrations, $FL = PX$, where F is the force exerted by the clamping screw, and P is the total reaction by all "rubber"

pieces. Since $P = FL/X$, it is evident that P is a maximum when X is a minimum.

Rockers as Beams.—It was shown above that because rocker R_4 (Fig. 84) is equally divided, the two pieces W_1 and W_2 will each receive twice as much pressure as will each of the four pieces W_3 to W_6, for which reason Fig. 83 was substituted for Fig. 84. In Fig. 85 is shown a method of proportioning the rockers R_1 and R_2 so that the middle piece W_2 receives one-half pressure from each rocker, thus having the same total pressure as pieces W_1 and W_3.

To facilitate proportioning leverages, all rockers, as well as the clamping lever A, were referred to as beams. The method of

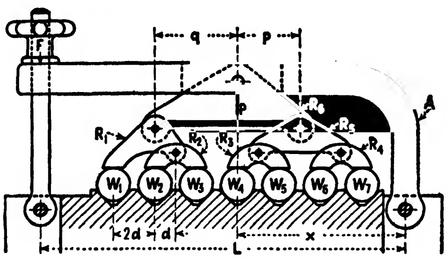


FIG. 87.

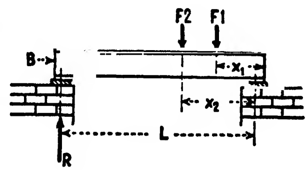


FIG. 88.

FIG. 87.—Clamps to hold seven pieces.
FIG. 88.—Illustrating action by using a beam.

figuring as referred to in Fig. 88 applies to all the illustrations. Based on this method, the following data are given, where N represents the number of pieces to be clamped:

$N = 2$. Use Fig. 84. Pivot rocker R_5 directly to the clamping lever A, and put the ends S_1 and S_2 on the work.

$N = 3$. Use Fig. 85.

$N = 4$. Use Fig. 83. Pivot rocker R_4 directly to the clamping lever A, and put rockers R_2 and R_3 on the work.

$N = 5$. Use Fig. 86 and proportion $m:n = 2:3$.

$N = 6$. Use Fig. 83.

$N = 7$. Use Fig. 87 and proportion $p:q = 3:4$.

If N equals 8, the arrangement is the same as for four pieces. If N equals 9, it is best to divide into groups of 4 and 5 and follow the scheme as for N equals 7. Such divisions of N as $\frac{N-1}{2}$ and $\frac{N+1}{2}$ will give the best arrangements.

CHAPTER VI

MACHINE VISES AND VISE JAWS

There are many cases where special vise jaws can be designed to fit vises supplied with milling and other machines, which will take the place of milling fixture. These vises are nearly all of substantial design and rigid construction and are very useful when supplied with the proper jaws. Many large manufacturing concerns have standards for such vise jaws, which can readily be adapted to a large variety of work.

A great deal of time has also been spent on the important point of quick-acting vises, although this feature has not been improved upon to any great extent.

Vise manufacturers who still stick to their original design do so probably because of the interchangeability of parts, rather than for any other reason. This is a great advantage when it comes to manufacturing and replacing broken parts.

Work held in the vise is the source of much comment between the tool designer and his superior, and frequently the designer is forced to design expensive milling fixtures which, in many cases, are nothing more than a huge vise. The fact that manufacturers supply the vise as part of the equipment of their milling machines demonstrates its general usefulness.

AN ASSORTMENT OF VISES

For general manufacturing purposes, the vise illustrated in Fig. 89 is a fairly representative type, and it can be clamped rigidly in almost any position on the machine table. It is this type of vise with which the tool designer usually comes in contact when designing jaws for special purposes. Swivel bases, with graduated scales for setting the vise at given angles, are a distinct necessity for toolroom work; but for manufacturing it is best to dispense with an extra movable surface coming between the cutter and the work.

In Figs. 90 to 93 are shown designs of vise jaws suitable for holding small, round stock while milling keyways or similar opera-

tions. Two larger shafts may be milled at the same time by providing jaws as illustrated in Fig. 94, when the limits of accuracy are sufficiently wide to allow for slight variation in the size of the bars. The wedge-shaped jaws force the bars down against the bottom of the vise even if they are not of exactly the same diameter. Figure 95 is a good method of holding stock of even size for gang milling a bar to a number of short lengths.

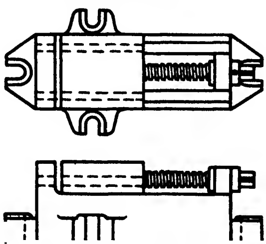


FIG. 89.—Machine vise for holding work.

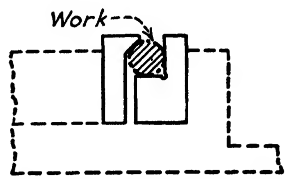


FIG. 90.—Vise with one wedge jaw.

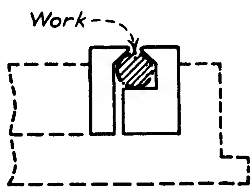


FIG. 91.—Here both jaws force the work down.

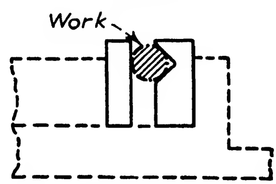


FIG. 92.—Here the fixed jaw has a V.

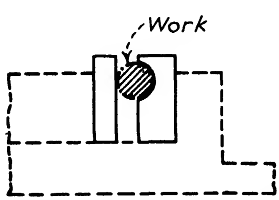


FIG. 93.—Where the fixed jaw fits the work.

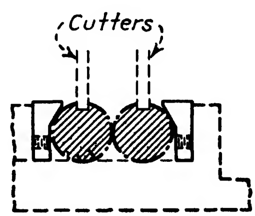


FIG. 94.—Clamping two bars at once.

An almost standard type of jaw is seen in Fig. 96. This kind is used largely in the toolroom for milling the clearance on form cutters, but it demonstrates a method applicable to other work where it is necessary to set the work over at an angle. Figure 97 shows a jaw in which the metal is cut away, as in a die, to hold a forging or casting of irregular shape. The dowel pins *AA* are for lining up and resisting the tendency of the jaws to move

sideways, caused by gripping on an irregular form. Without these pins the work of resisting this lateral motion would come entirely on the threaded part of the screws holding the jaw in position. Also, in changing the jaws from one vise to another, correct alignment is immediately secured.

A similar die-form jaw is shown in Fig. 98. This gives an idea how a piece may be held rigidly by this method for taking a

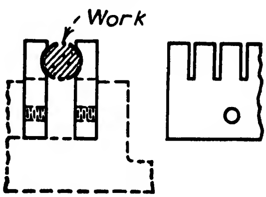


FIG. 95.—Jaws for cutting bars into short lengths.

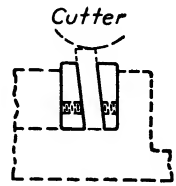


FIG. 96.—Angular jaws give clearance for milling form cutters.

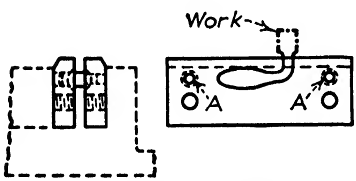


FIG. 97.—Jaws cut away to fit special work.

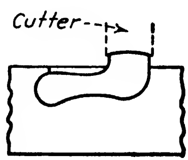


FIG. 98.—Detail of the form cut into jaw.

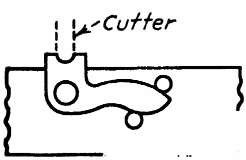


FIG. 99.—Sometimes pins can be used to locate irregular flat work.

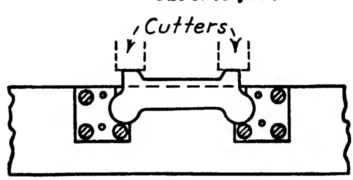


FIG. 100.—False or special jaw pieces for irregular work.

broad heavy cut across a piece of somewhat delicate form. In Fig. 99, the piece is seen located by means of pins. These pins should be made as short as is consistent with proper locating in order to save time in taking out one piece and putting in another.

Another phase of the die-type jaw is shown in Fig. 100. In this case pieces are added to the jaws which locate the work. This is

probably a cheaper method in many cases, and it also lends itself to easy alteration in the event of slight change in the size or shape of the part being machined. This will appeal to those having had experience on batches of the same casting coming from different foundries.

A very neat method of holding small turned pieces of uniform size, screws, pins, etc., is seen in Fig. 101. The number of

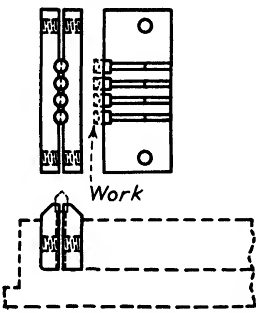


FIG. 101.—Holding several small pieces.

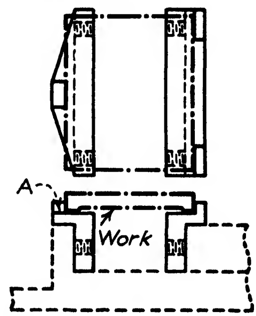


FIG. 102.—Extending the jaw capacity of a chuck.

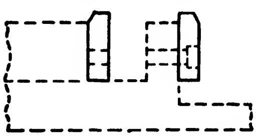


FIG. 103.—Another method of increasing chuck capacity.

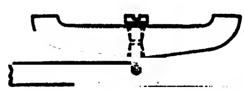


FIG. 104.—Compensator or equalizer for leveling work.

pieces that a clever operator can mill in a short time by this method is surprising.

The extended jaw, shown in Fig. 102, is a type of very wide application and specially adapted to holding thin flat pieces beyond the capacity of the ordinary range of the vise. The part of the jaw *A* in contact with the side of the piece is cut away to form a gripping edge; this is a very effective method of resisting any lifting tendency. Figure 103 is another application of the case when the work is too long to go between the standard jaws of the vise but is hardly adapted for heavy work.

FIG. 105.—Another method of holding equalizer.

Vises with Compensators.—Three methods of the application of compensating equalizers, by which two pieces of unequal size

may be held rigidly at one time, or a rough casting gripped on two points, are illustrated in Figs. 104 to 106. In Fig. 104, the compensator is free to move about the retaining screw; while in Fig. 105, the retaining screw is part of the compensator, and the

FIG. 106.—This equalizer is held by a pin.

movement takes place in the clearance hole in the jaw. In Fig. 106, the compensator is retained in position by a fulcrum pin. It should be noted that in neither case does any pressure come on the retaining device; the pressure is transmitted directly through the compensator to the vise jaw, on which it rests. The examples

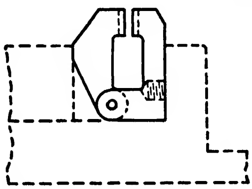


FIG. 107.—Swivel jaw for small work.

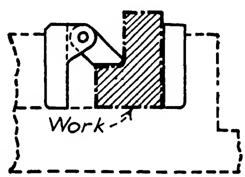


FIG. 108.—This jaw forces the work down.

shown in no way cover the wide range of designs based on this principle.

A type of swivel jaw very suitable for holding small pieces is shown in Fig. 107. It should be observed that the fulcrum pin is

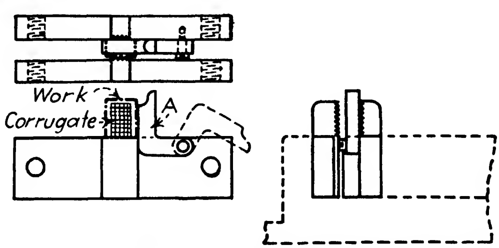


FIG. 109.—Gage for setting work is part of chuck.

in such a position that when the jaw is closing on the piece it has also a slight downward motion just sufficient to counteract the tendency of the piece to rise. Another swivel-piece jaw is seen in Fig. 108. With this device the work may be depended upon to bed itself thoroughly against the bottom and opposite side.

In Fig. 109 is shown the application of a gage *A* for setting the work in the vise; it is attached to the jaw itself. After the work is set correctly, the gage may be swung on one side out of the path of the cutter, as indicated by the dotted lines, and as easily brought into position again for setting the next piece.

In Fig 110 is seen a vise jaw of a more complicated nature but of very wide application for holding pieces of delicate form, where gripping them in the ordinary way would cause distortion. The hardened pins *A* are held out from the jaw by the flat springs *B*. When it is seen that all these pins are in contact with the work, they are locked in position by the clamping pin *C*, running through the jaw. The vise is then tightened down on the piece in the ordinary way.

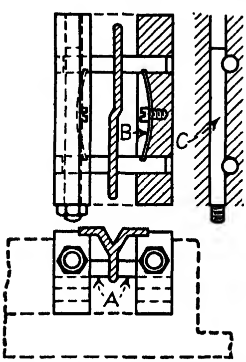


FIG. 110.—Special jaws for delicate work.

It is very necessary that the special jaws described above should be fitted to the vises in a rigid and workmanlike way. Most of the vises on the market are provided with means for doing this. Care should be taken that the hardened jaws are perfectly flat and bed all the way along on their supporting surface. Any burrs on the tapped holes should be removed, and the corners at the bottom of the jaw should be of sufficient radius to make sure they are not touching at the bottom and top only, as shown in Fig. 111.

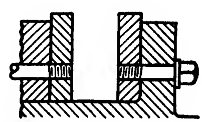


FIG. 111.—Fitting special jaws.

To get this perfect fit, which is so necessary to eliminate all spring and insure the job's being held squarely, hardened jaws should in all cases be ground. Not only is a higher class finish given to the work held in rigid jaws, but faster feeds and speeds and fewer broken cutters more than compensate for extra workmanship here.

The material generally used for vise jaws is machine steel casehardened. Where the number of the pieces to be machined or the design of the jaw warrants it, it is advisable to use tool steel,

hardened. Cast iron may occasionally be used; but when using this material, it is necessary to design the jaws considerably thicker.

MORE SPECIAL VISE JAWS

The engraving shows the construction of milling-machine vise jaws for machining four bosses on a U-shaped casting, as shown at Fig. 112.

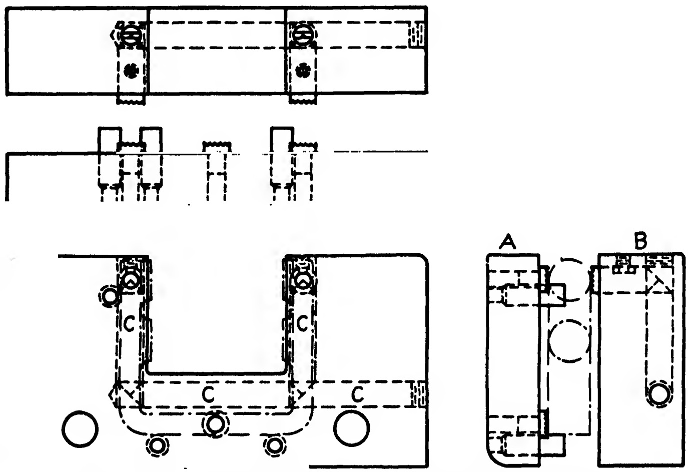


FIG. 112.—Special jaws for milling U-shaped casting.

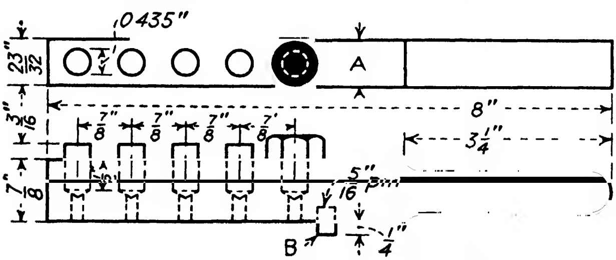


FIG. 113.—Holder for castellating nuts.

The fixed jaw *A* has a three-point bearing and three locating pins for the casting. The movable jaw *B* bears against the casting at two points, and on account of the rough surface of the casting it was necessary that these points should adjust themselves to suit the casting. The clearance that was necessary for the milling cutter made it impossible to locate a swivel. A series of cone-pointed pins *C* were arranged as shown, so that

the motion of one point was transmitted to the other through this series.

In connection with the pair of plain jaws supplied with the vise, the loading devices shown in Figs. 113 and 114 may be used. The device shown in Fig. 113 is used for castellating square or hexagonal nuts, five at a time. It can be varied to suit the demand. The pins space the nuts, while the stop *B* locates

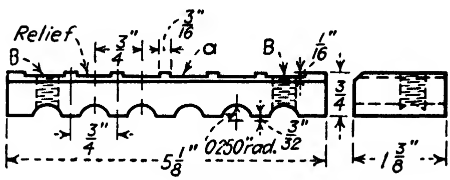


Fig. 114.—Jaws for round pins.

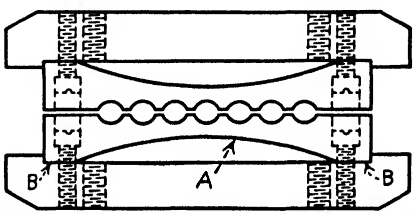


Fig. 115.—Another design for same work.

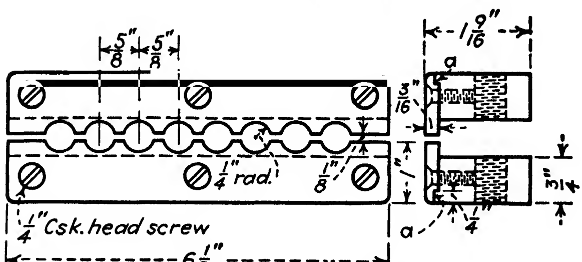


Fig. 116.—For holding bolts close to head.

the whole with reference to the cutters. The piece *A* is less than the width of the nuts, so that the jaws grip the work only.

Design of Jaw for Holding Pins.—A design of jaw for holding pins, or any similar parts made of round stock, is shown in Fig. 114. These jaws contour the work as shown, and the back is relieved at *a*, the object being to equalize the grip on the parts held. The tapped holes *B* correspond to the fastening bolts of the vise.

A more effective design is shown in Fig. 115. This has a block fast to the vise, backing the jaw which is made fast to the block itself. The jaws are arched out at *A* and are a particular fit at the corners *B*, tending very slightly to bow the jaw.

For milling operations on countersunk or round-head bolts that have the threads close to the head, or for flat pieces such as disks, jaws of the form shown in Fig. 116 are used. The grip portion

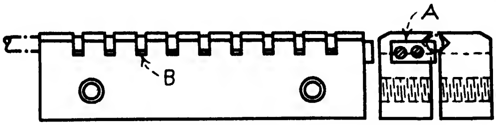


FIG. 117.—Somewhat similar to Fig. 95.

is a thin steel plate ¼ or even ⅛ in. thick, contoured to the work. The jaws are more conveniently made in two pieces, as shown, a plate and a block. The work is gripped by the plate, fast to the block, which is stepped out at *a* to take the thrust. Only the false or auxiliary jaws are shown. These are fastened to the vise jaws.

Jaws Used When Cutting Off Short Pieces.—For cutting off short pieces of stock of any shape or for milling at several points

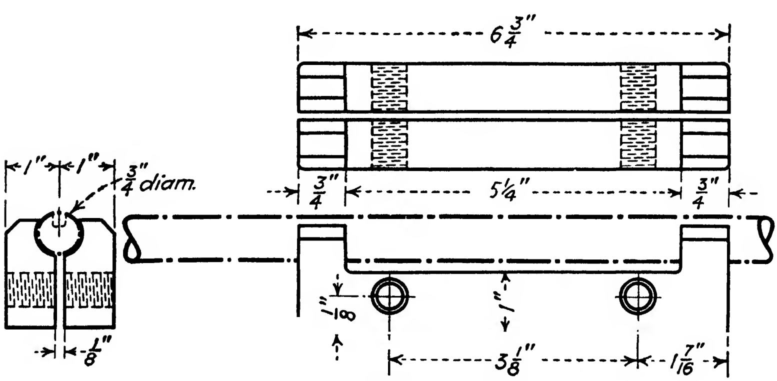


FIG. 118.—Straddle jaws for milling keyways.

on a single piece, the jaw is grooved lengthwise to the shape of the stock. A stop is fastened at *A* (Fig. 117). The cutters are correctly spaced for the operation on the work and cut their own pathway *B* through the jaws, which are afterward hardened and replaced in the vise, the cutter ways being first ground for clearance. This is similar to Fig. 95.

The same design of jaw grooved lengthwise is used for straddle milling the sides of a piece along the jaws or for milling a keyway or groove, as in Fig. 118. The grip of the jaws straddle the position of the operation, so as to avoid any pressure on the cutters.

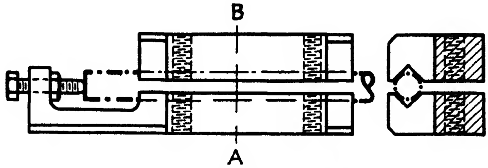


Fig. 119.—Stop screw for locating work.

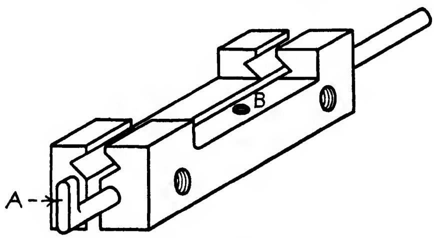


Fig. 120.—Other V jaws for round work.

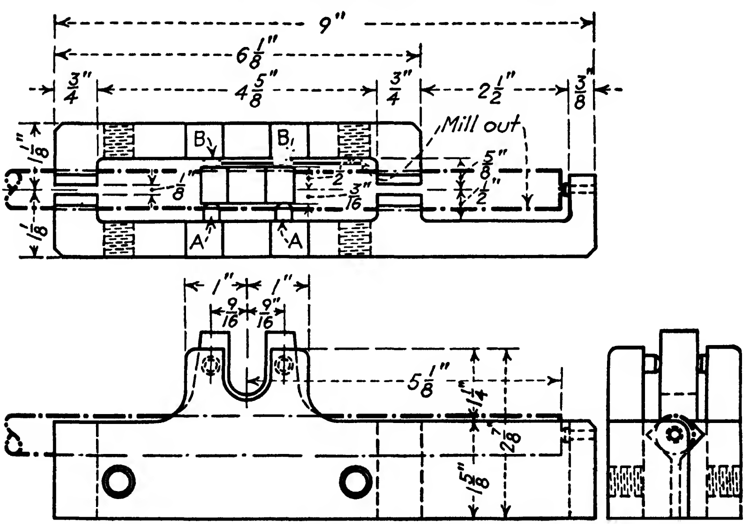


Fig. 121.—Jaws for milling an offset fork.

Two very handy designs are shown in Figs. 119 and 120, in that they are capable of holding various sizes of either round or square stock and are also fitted with adjusting stops. The slid-

ing stop rod A (Fig. 120) is set by means of the headless screw at B. Longer pieces have a stop on the miller table itself, fixed with reference to the cutters.

Jaws Used When Milling Projections.—For shafts that have projections requiring milling operations, a typical form of jaw is shown in Fig. 121, where the projecting part in the form of a fork is offset. Pins are inserted at A and B. The different lengths of pins hold the offset in position for milling, while the longitudinal groove grips the shaft. These pins are placed so as best to resist the thrust of the cutters.

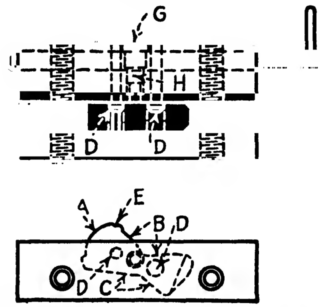


FIG 122.—Special jaws for gun work

When the work takes irregular shapes, such as small parts for rifles, the sectional contour is milled along the entire length of a

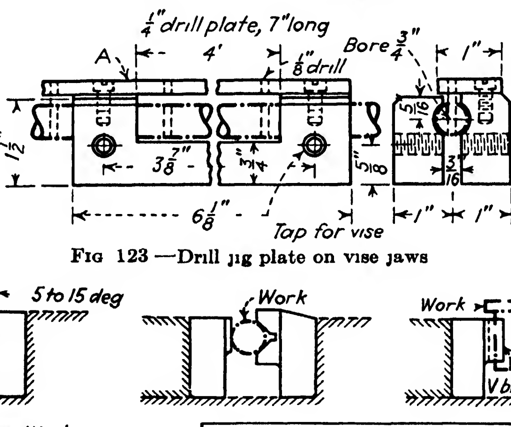


FIG 123.—Drill jig plate on vise jaws

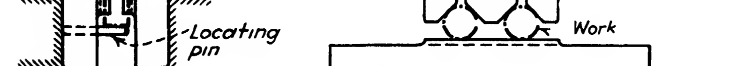


FIG 124.—Jaws for holding cylindrical pieces

piece of stock. The piece A (Fig 122) is a detail drawing of the hammer of a magazine rifle. The contours at B and C show the cross section of a length of stock so milled. The stock is next sawed into approximate widths, and the holes D drilled to establish locating points for succeeding operations. Corresponding to

these holes, pins are inserted in the jaws so as to present the work to the cutters for milling the notch E. This notch is a particular dimension from some other surface, also located from the same holes. These holes sometimes have no other use than to locate the piece. They are employed whenever they facilitate the manufacture of the part, particularly where the work must be very accurate. The shaft is provided with a cam turned at G. A half turn of the shaft operates the spring pin H to strip the work off the locating pins.

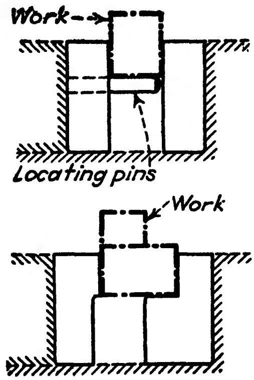


Fig. 125.—Jaws for flat pieces.

In Fig. 123 is shown a convenient method of using the vise as a drill jig. The plate A provides for guiding the drills, and the jaws are cut away on the surface under the piece being machined, as there should be no pressure on the drill.

Accompanying illustrations (Figs. 124 to 129) show a variety of vise jaws and fixtures which will suggest their application to many different kinds of work. There are few shops in which one or more of these designs cannot be used, with such modifications or adaptations as may be necessary to suit the work in hand. The designs in Figs. 124 to 127 are simple; but while Figs. 128 and 129 are somewhat more complicated, they will also be found to have a number of applications.

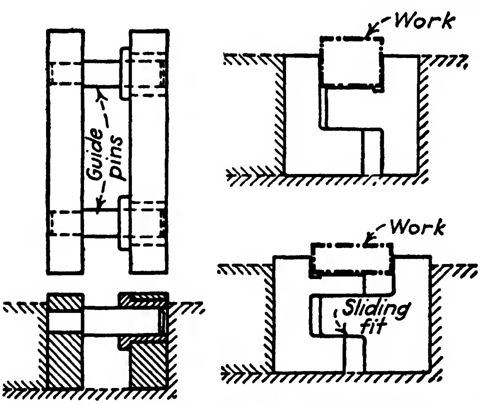


Fig. 126.—Methods of aligning vise jaws.

Indexing in the Machine Vise.—With milling-machine vises equipped with special jaws, many small troublesome parts can be milled with dispatch in a hand miller. When, however, several cuts are to be taken at accurate related angles to one another, rapid and accurate indexing is called for.

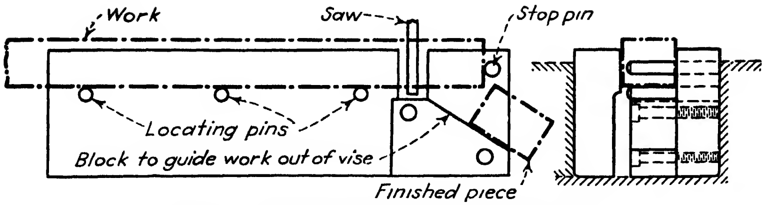


FIG. 127.—Vise jaws for cutting off bar stock.

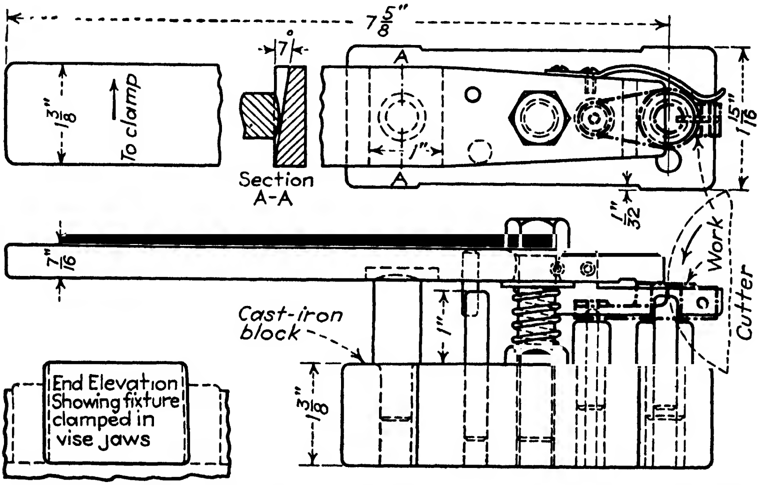


FIG. 128.—Milling fixture with a quick-acting clamp. It is held in a standard vise.

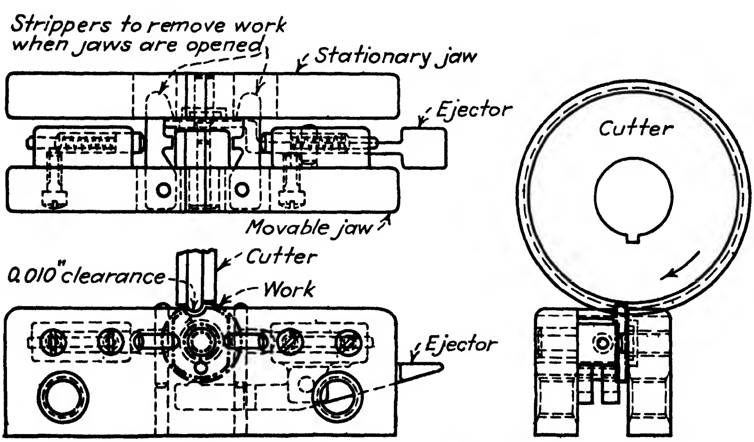


FIG. 129.—This vise-jaw milling fixture has been found very efficient.

Such problems can be solved by using an ordinary milling-machine swiveling vise and fitting it with special jaws and indexing stops. For locking the vise in the indexed positions, the long screw *A* (Fig. 130) was substituted for the regular clamping screw. Besides being long enough to be conveniently reached, it is provided with a handle for ease of operation.

Referring to Fig. 130, the two round pieces in the vise are to be cut away to the center line on the end and are to be straddle milled at 90 deg. from the first cut. These pieces are shown enlarged at *B*. At the left, the vise is shown in position for making the first cut with cutters *C* and *D*. At the right, it is shown indexed 90 deg. for making the second cut with straddle mills *F* and *H*. As the second cut is a light one, the pieces can be fed rapidly between the cutters.

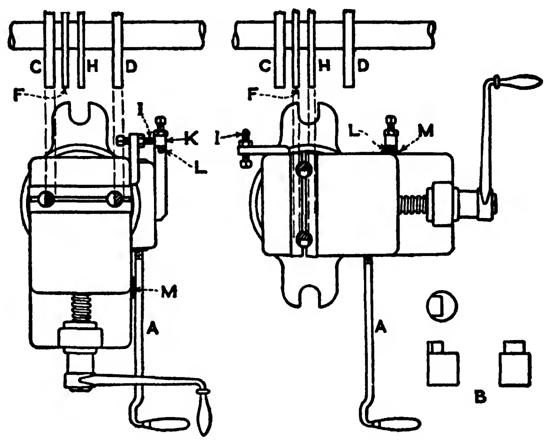


FIG. 130.—Indexing in a milling-machine vise.

When the vise is positioned for the first cut, the stop screw *I* is in contact with the fixed stop *K*; but when it has been indexed 90 deg., stop screw *L* contacts the stop plate *M*. Fine adjustment is made by adjusting the stop screws. In some jobs, the cuts may vary in depth, so that it may be necessary to use cutters in which the diameters bear the proper relation to one another.

Toolmakers' Vise with Swivel Jaws.—A toolmakers' vise, having auxiliary jaws which swivel in the vertical plane and are so arranged as to hold straight or tapered work either vertically or at an angle, is shown in Fig. 131.

The auxiliary jaws *A* and *B* are pivoted to the regular jaws and bear in circular seats therein, so that the pressure of holding the work is not borne by the pivot pins. Taper pins *C* and *D* locate the auxiliary jaws in any of the angular positions indicated

by the half-round notches *F* and *H*, which can be spaced at any desired angle to permit work to be held at that angle.

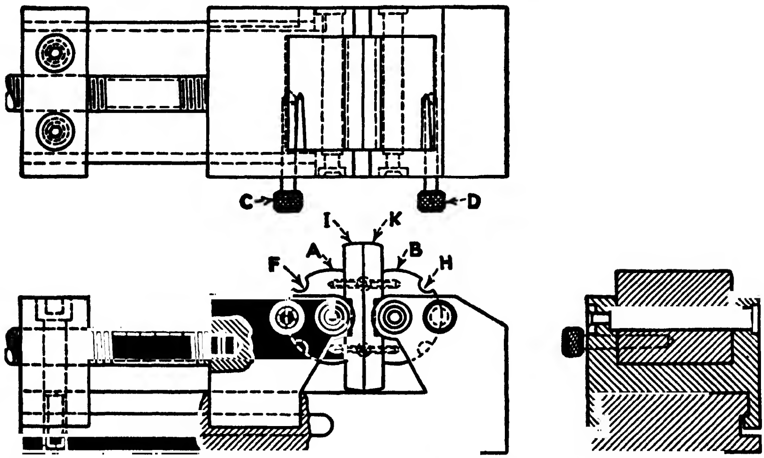


Fig. 131.—Auxiliary jaws are pivoted and bear in circular seats to relieve pins from undue pressure in clamping.

To permit wide work to be clamped without interference from the ears through which the pivot pins pass, the notched plates *I* and *K* are attached to the flat faces of the auxiliary jaws. For holding tapered work, pins *C* and *D* can be removed, permitting the auxiliary jaws to adjust themselves to the taper. The other details are the same as in an ordinary toolmaker's vise.

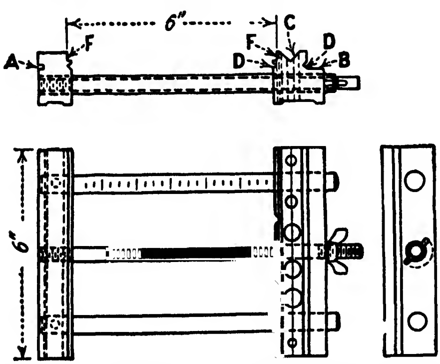


Fig. 132.—Details of drill vise to replace parallels and clamps.

Timesaving Vise for the Drill Press.—The vise illustrated in Fig. 132 was developed to take the place of parallels and clamps in drill-press work. It consists of a stationary and a sliding jaw, two parallel rods, a central screw, and a thumb nut for adjusting the sliding jaw. One of the parallel rods is graduated in quarter inches for convenience in opening the vise a predetermined amount.

The stationary jaw has a rectangular groove at *A*, and the sliding jaw has a flat at *B*, both of which are for accommodating clamps for holding the vise in place on the drill-press table. Both jaws have vertical and horizontal V grooves in their inner faces, and the sliding jaw has a V groove in the top at *C*. The small V grooves *D* are for a toolmaker's clamp for holding round work in the V groove in the top of the sliding jaw, as indicated in Fig. 133. Steps in the inner faces of both jaws at *F* are provided for holding die blocks and other flat work, as shown in Fig. 134. The vise can also be used as a base

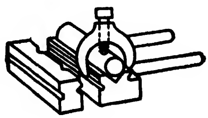


Fig. 133.—Holding round work with toolmaker's clamp.

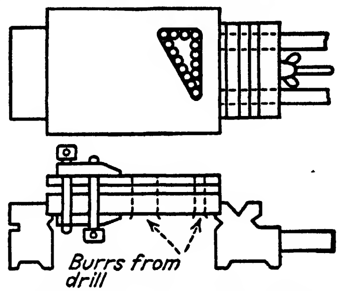


Fig. 134.—Holding flat work in jaw steps.

for a dial indicator, as shown in Fig. 135. The indicator is mounted on a rod which is held in one of the vertical V grooves.

As accessories, V plates, as shown at the left in Fig. 136, are provided for both jaws. They have three slots at the bottom, the outer ones permitting the plates to straddle the parallel rods, on which they rest when in place. The center slot is for clearing the screw. One of the uses for the V plates is indicated at the right, where a bushing is held for drilling the oil holes.

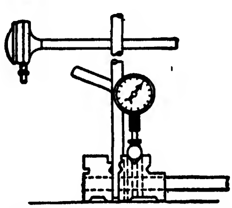


Fig. 135.—Used as base for dial indicator.

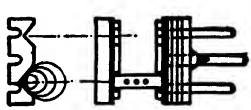


Fig. 136.—V plates and one of their uses.

Simple but Effective Milling Vise.—All who have attempted to hold several flat pieces in a vise know of the tendency of those in the center to work up above the rest. This not only makes it difficult to get all the pieces milled to the same dimension but also tends to loosen the pieces in the vise.

The vise shown in Fig. 137 overcomes both these tendencies and holds a number of pieces as firmly as one. This is from the shop of W. H. Nichols, who made the vise shown for holding the side plates of his rayon pumps. The secret of the vise is that the work is held between end plates that are tied together by substantial side bars which effectually prevent any tendency on the part of the jaws to open up. Being held centrally between these side bars and clamped by a substantial screw, the work is held firmly regardless of the depth of cut that is taken.

USING DIAL INDICATOR TO SECURE ACCURATE CLAMPING

Boring the spindle hole in one-piece turret-lathe beds presents an unusual problem of alignment, since the work must be clamped

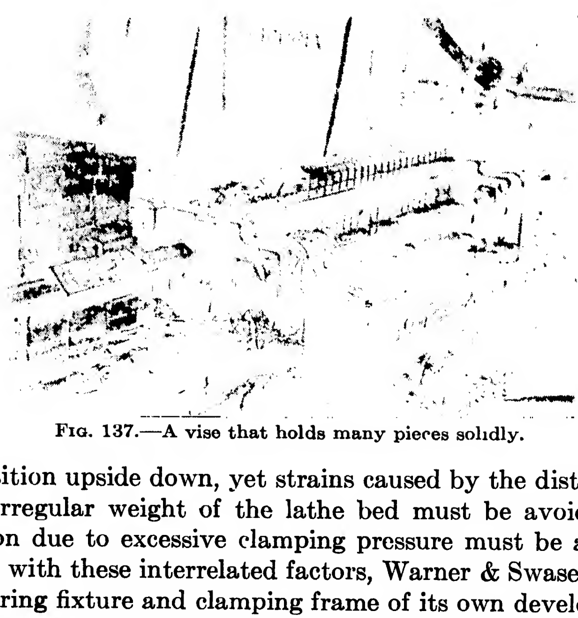


Fig. 137.—A vise that holds many pieces solidly.

into position upside down, yet strains caused by the distribution of the irregular weight of the lathe bed must be avoided and distortion due to excessive clamping pressure must be avoided. To cope with these interrelated factors, Warner & Swasey uses a large boring fixture and clamping frame of its own development, and the base plate of this is bolted to the boring-mill table with the aid of an outboard support.

The fixture shown in Fig. 138 consists of three upright braces, one which contains the outside boring bar pilot, plus a special upright bearing the inside boring bar pilot at the end of the fixture. Between the two boring bar pilots is located a special clamping frame. The lathe bed is inverted, and its finished way rests on the three upright braces, with the lathe head hanging in front of the cutting head of the boring mill and resting

within the clamping frame. In this position the surface to be machined is more convenient to the operator.

Single Screw Controls Alignment.—Partly supported by the braces, the weight of the lathe head is further supported within the clamping frame by two adjustable rest pads bearing on tapered blocks joined by a single equalizing screw. The screw makes possible the simultaneous adjustment of both pads by turning one hand knob until the weight of the entire lathe bed rests in the desired vertical position on the two pads and the three upright braces. Such position is naturally determined by the desired alignment of the bed to the boring-bar bearing pilots.

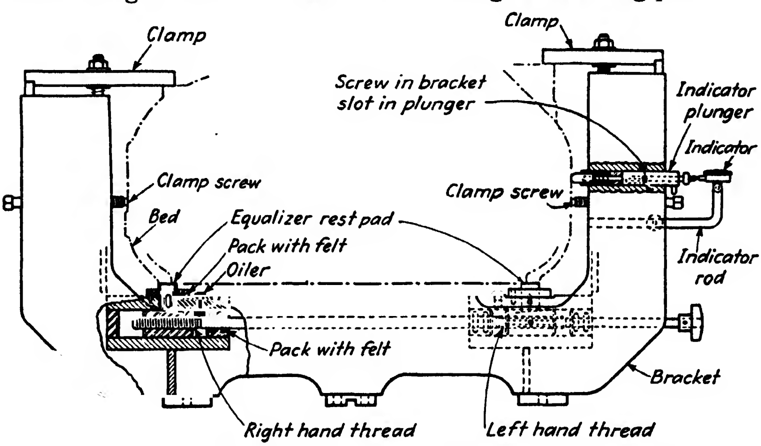


FIG. 138.—Special Warner and Swasey fixtures for boring mill.

When this has been done, the head must be clamped to prevent lateral movement. To avoid distortion which might result from excessive pressures from the clamp screws at the side of the special frame, a dial indicator setup is used to gage the clamping strain. The indicator is brought to bear on the end of a spring-loaded plunger which rests on the left side of the lathe head so that any strain developed in the workpiece can be read directly from the gage. Then the clamp screw on the opposing side is tightened until a 0.003-in. deflection is recorded. After this, the near screw is tightened until the gage again reads zero. Thus, the work is truly aligned with sufficient pressure to give rigid clamping and no distortion.

Once located horizontally and vertically, the workpiece is further held in place by bringing to bear on it clamps at the top of the frame and tightening them. Then the work of boring the spindle hole can proceed.

CHAPTER VII

CLAMPS AND CLAMPING METHODS

Proper designing and making of clamps or holding devices is a very important part of the fixture designer's work. Faulty clamps may easily cause much spoiled work as well as injury to the operator. Well-designed clamps play an important part in the rapid handling of the work.

There are four main points to be considered in designing or in selecting the clamp to be used on any fixture. These are: strength of the clamp; applying power at the proper point; the bearing points for the clamp both on the work and at the back end; and the method of preventing the clamp from turning during the clamping operation. To this might be added a fifth consideration: the ease and rapidity with which the clamp can be operated.

Instead of advising as to the particular clamp to use on fixtures of various kinds, it seems best to show a large variety of clamps and clamping methods that have proved satisfactory in work of widely varying character. Some of these require very little detailed explanation. In general, it may be said that it is usually advisable to provide a spring underneath a clamp to raise it from the work as soon as the pressure is released. This not only saves time but also lessens the work of the operator.

Many of these clamps are shown with little or no explanation. This is because it is felt that the design and operation are clear when the captions are read. As has been stated before, the main object is to show methods from which other ideas can be obtained or to permit the adaptation of the designs given to suit the work that the designer or toolmaker has in hand.

Some of the designs will be found quite similar, but there are slight differences which may appeal to some as being better adapted to their particular use.

A Quick-acting Clamp.—A quick-acting clamp is shown in Fig. 139. This clamp will be found useful in operating a V block, as it overcomes the necessity of giving an ordinary screw several turns

in order to get it back far enough to clear itself. The plunger *A* should be a sliding fit in the threaded collar *B*, which has a splined hole in which a ¼-in. pin *C* works. The length of this splined hole governs the movement or clearance wanted for operating the V block. It is practically an adjustable bayonet joint. The threaded collar permits easy adjustment of the clamping distance.

An important point in making this scheme work out satisfactorily is to make the tapped hole in which the threaded collar works a rather stiff fit. The reason for this is that when the operator reverses the pin *A*, the collar will stay in its place, thus allowing the pin *C* to free itself from the locking end of the splined hole.

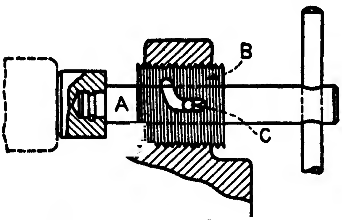


FIG. 139.

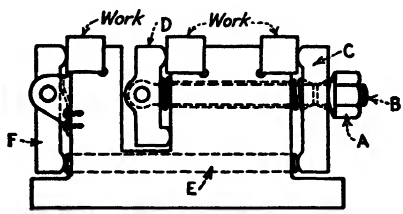


FIG. 140.

FIG. 139.—Quick-acting clamp.
FIG. 140.—Clamping three pieces with one bolt.

The threaded collar also permits the locking position of the plunger *A* to be adjusted in or out, as may be desired.

Clamping Three Pieces with One Bolt.—The operation of three clamps on as many separate pieces of work with one bolt is shown in Fig. 140. The clamps not only hold the work like a vise but also nip and draw it down against the surface of the fixture. They should be hardened, and suitable springs placed beneath them so that as soon as the pressure against them is released they will spread open and thus enable the operator to clean the surface of the fixture and also insert the part to be machined.

One of the important points in designing milling or profile fixtures is to do away with as many clamping bolts as possible. Operators waste much time tightening up several pressure clamps when one would be sufficient. These clamps are frequently in very awkward positions. For this reason, Fig. 140 is shown to illustrate what can be done by the tightening of one bolt or nut.

As the nut *A* is tightened, it draws the bolt *B* forward, thus tightening the clamp *D*, at the same time acting against the clamp

C. The lower end of *C* also forces the rod *E* forward, and it in turn works against the clamp *F*. Thus the three clamps are operated by one nut only.

This is probably as good an illustration as can be found of the endeavor to reduce the time of handling of work to a minimum. And this has been worked out with almost no complication of parts, which is to be avoided as much as possible. In some cases of combination fixtures, it is more or less difficult to place the work in position, but in this case no such objection can be made. The three pieces are easily placed in their respective positions without having to hold the clamps out of the way, as springs are ingeniously arranged to take care of this. And a single nut, which could just as well be a handwheel, clamps them all at one operation.

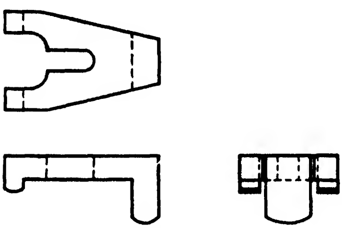


Fig. 141.

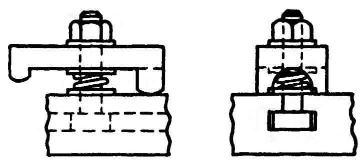


Fig. 142.

Figs. 141–142.—Three-point bearing clamps.

There are many cases, however, where the desire to do everything possible with one bolt or locking device leads to impractical combinations of mechanical motions which cannot help being complicated, often to a degree that makes them useless as a practical aid to quantity production. One point to be watched in combination fixtures, or indeed in fixtures of any kind, is the ease with which they can be cleared of chips so that the next piece will seat squarely and be properly located in the fixture.

The proper seating of work in jigs or fixtures has much to do with the accuracy secured in the finished piece, and this is especially to be watched in combination fixtures of any kind.

Figures 141 and 142 are three-point bearing clamps, two bearing points in front and one in the rear. Attention may be called to these bearing points' being rounded, which allows the clamp to seat itself properly on the work and to compensate for any variation in the size of the part to be clamped. This is particularly useful when a roughcasting is to be operated on.

It is well to provide a spring underneath the clamps, as shown in Fig. 142; this will reduce the time otherwise required to manipulate clamps of this description.

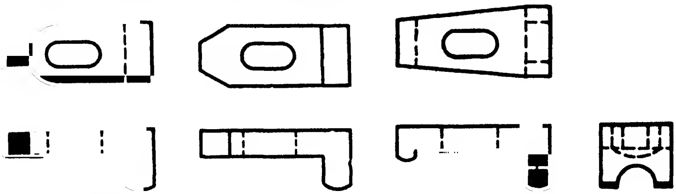


FIG. 143. FIG. 144. FIG. 145.
FIGS. 143–145.—Three other clamps that bear at three points.

Figures 143, 144, and 145 are similar to Figs. 141 and 142, except that the two points of bearing are in the rear and the single point in the front. Figure 143 is the style of clamp frequently

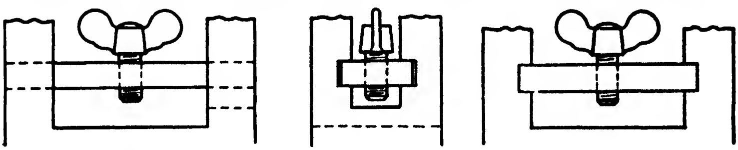


FIG. 146. FIG. 147.
FIGS. 146–147.—One type of clamp for box jig construction.

used for holding drill jigs, milling fixtures, lathes, fixtures, etc., to the table, bed, or faceplate of the machine.

Figures 146 and 147 are also similar and are generally used in box-jig construction. They can be easily removed by sliding the

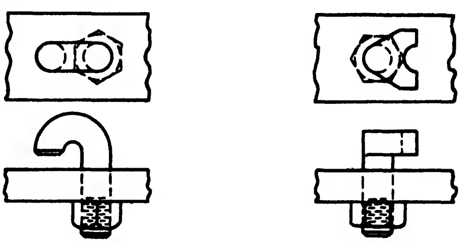


FIG. 148. FIG. 149.
FIGS. 148–149.—Two kinds of hook bolts.

plate longitudinally. The clamping screw is carried in a plate which is held in place by the retaining grooves.

Figures 148 and 149 are good examples of what are generally called hook bolts; the bearing point of the hook should always be as close to the bolt as is possible.

Figure 150 is a design of clamp not frequently seen in use, although for light clamping it has many advantages; it is quick to operate and takes up very little room, which is so important in tool designing and toolmaking.

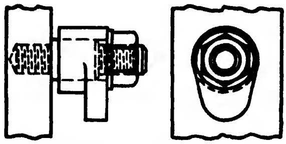


FIG. 150.—Swinging hook clamp for close places.

Figure 151 is the style of clamps most frequently used in drill-jig construction, especially table or box jigs. With this design the piece is held in the jig by one point striking in the center. In

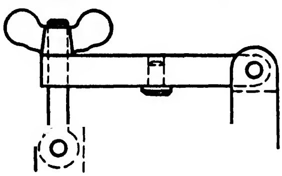


FIG. 151.

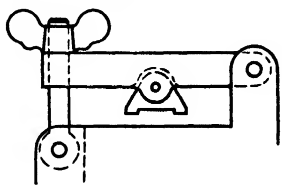


FIG. 152.

FIGS. 151–152.—Two designs of lever clamps.

Fig. 152, the same style of clamp is used, except that it has two self-adjusting bearing points and in some instances three points.

FIG. 153.

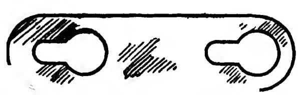


FIG. 154.

FIG. 155.

FIG. 156.

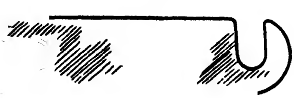


FIG. 157.

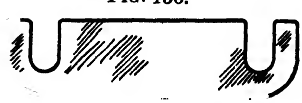


FIG. 158.

FIGS. 153–158.—Six types of straps for jig use.

Figures 153 to 158, inclusive, show a few designs for jig straps which are the most commonly used. Figure 153 is what may be called the swinging type; the others are all removable. The

material generally used for making straps of this description is a good grade of machine steel.

Figures 159 to 164, inclusive, illustrate the principal methods of holding clamps from turning while the nut or bolt is being tightened on them. The tool designer or toolmaker too often overlooks this important point and does not seem to realize the advantage of properly holding them.

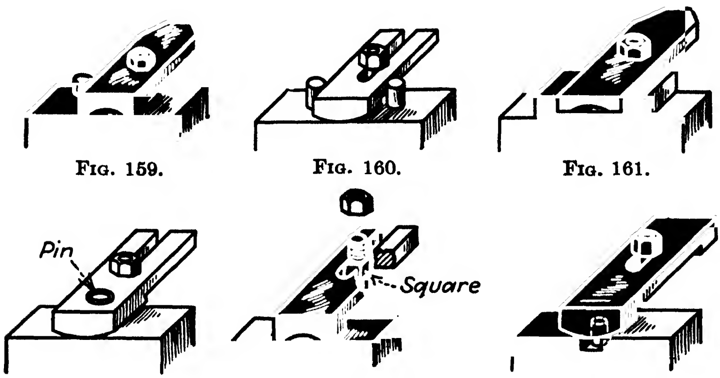


Fig. 159. Fig. 160. Fig. 161.
Fig. 162. Fig. 163. Fig. 164.

Figs. 159–164.—Six other jig straps, showing how they are used.

Figures 159 to 161 are styles commonly used in drill-jig construction, while Figs. 162 to 164 are most frequently found in use on milling fixtures. The object of securing clamps in this manner is to get more rapid production from the tool to which they are assigned; and if only a second can be saved in the process of

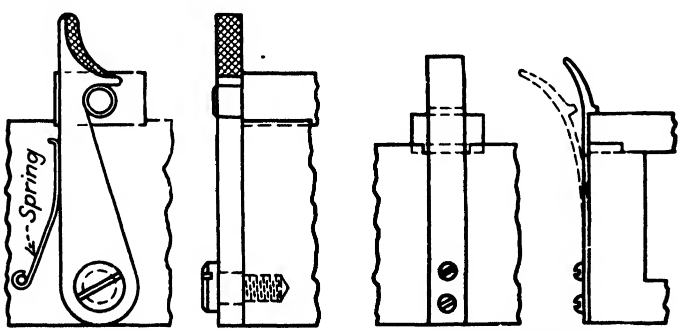


Fig. 165. Fig. 166.

Figs. 165–166.—Latches for holding jig lids in place.

tightening down the clamp on the work, that second means many hours if a great quantity of work is to be done.

Figures 165 and 166 show two designs of latches, such as are used on small jigs for holding down a lid or plate which contains

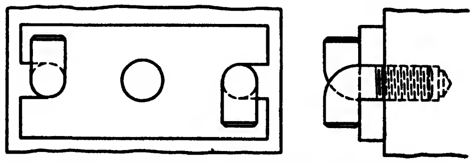


FIG. 167.—Holding screw with hooked head.

bushings or binding screws. Latches are made in many different styles. Sometimes the hook screw or lock screw is styled as a latch, probably because it is used for the same purpose. Examples of these screws are shown in Figs. 167 and 168. It is unnecessary to describe them further, as the illustrations speak for themselves.

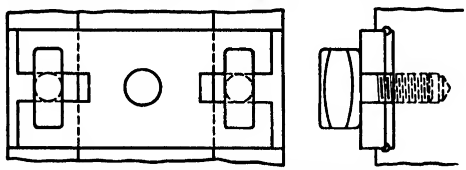


FIG. 168.—Cross-headed screw.

Figure 169 shows the design of an eccentric pin which is removable, but by threading the end and using a nut and washer it can

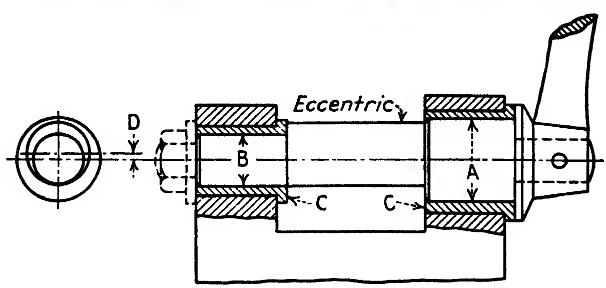


FIG. 169.—Eccentric-pin clamp, removable or with nut.

be held in place, thus making it stationary, as indicated by dotted lines. The eccentricity D varies from $\frac{1}{16}$ to $\frac{1}{4}$ in., depending entirely upon the size of the pin. The diameters A and B are made a sliding or working fit in the bushings C. These bushings are generally made of cold-drawn steel and casehardened.

Figure 170 is another design of eccentric pin working in the body of the jig, and the illustration shows it operating two bolts *B*, *B*. These bolts are, in turn, attached to a strap *A*. The pin, it will be noticed, is eccentric on both ends.

When the lever *C* is forced down, the screw *E* will bear against the work, and in case of any variation in the size of the work, such

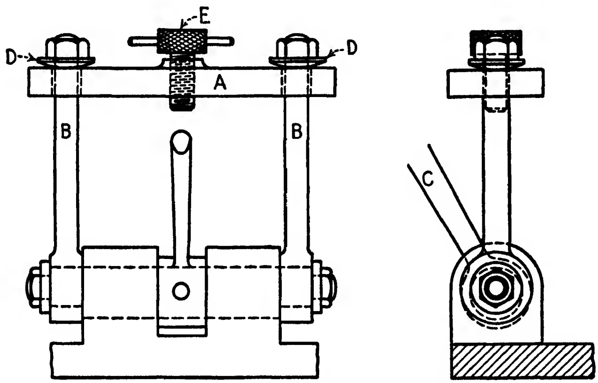


FIG. 170.—Another design of eccentric-pin clamp.

as a roughcasting, this screw can be adjusted to suit. The washer *D* should be rounded on the side bearing against the strap, which will allow an equal clamping stress on each of the bolts.

Figures 171 and 172 show two designs of swinging binders, which are both used considerably in drill-jig construction.

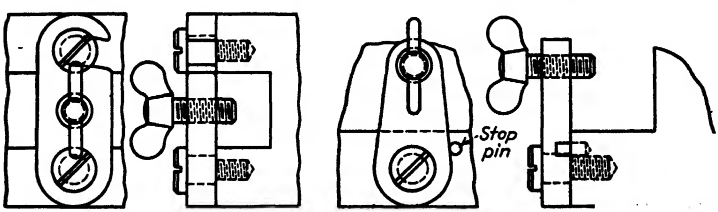


FIG. 171. FIG. 172.

FIGS. 171–172.—Two kinds of swinging strap clamps.

Figure 171 is the more popular for the reason that it can be made very small and by a good proportion its strength maintained. It has the advantage over Fig. 172 of having two screws instead of one to take up the thrust of the binding screw.

Figures 173 to 176 show the construction of the sliding bushings which are so often used for holding the work as well as piloting the

drill. The clamp is used in all cases for forcing the bushing against the work. Attention may be first called to Fig. 173 in this design; the bearing points are rounded to compensate for any variation in the height of the work and always allow the clamp properly to seat itself preparatory to the thrust of the bind-

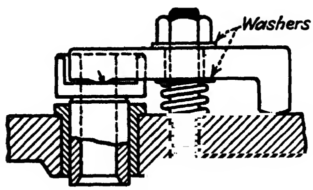


FIG. 173.

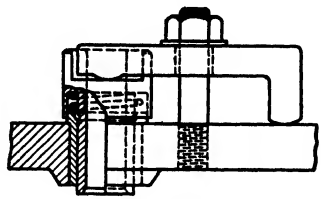


FIG. 174.

FIGS. 173–174.—Clamps that hold bushings against the work.

ing bolt or nut. A spring is placed directly beneath the clamp so that it will automatically bring the clamp back to its original position when the nut is released. If the slot in the clamp through which the bolt enters is elongated, it is advisable to place washers beneath the nut and between the clamp and spring as shown.

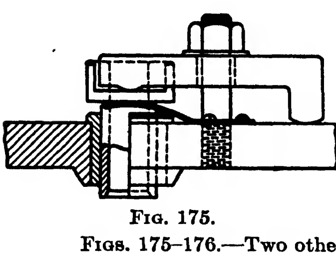


FIG. 175.

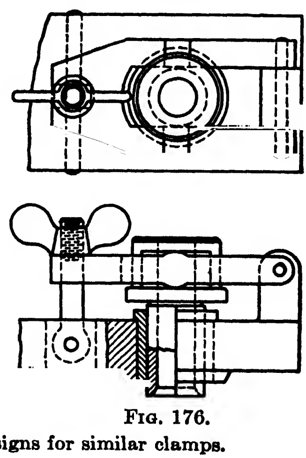


FIG. 176.

FIGS. 175–176.—Two other designs for similar clamps.

Figures 174 and 176 are of similar design. The spring in this case, instead of being placed under the clamp, is directly beneath the head of the clamping bushing in Fig. 174; this spring is a coiled spring and is protected from dirt and chips by a specially designed head on the bushing. In Fig. 175, a flat spring is shown; in this case, it is not necessary to protect the spring from dirt, chips, etc.

In either case, these two designs have the advantage, as the spring raises the bushing as well as the clamp as soon as the binding nut is released; while in Fig. 173, the clamp only is released, and it becomes necessary for the operator to lift the bushing when removing or placing the part to be drilled.

Figure 176 shows another way of operating these bushings. It is somewhat objectionable, owing to the fact that it is expensive, and it has no advantages over the preceding designs.

Several Good Clamping Devices.—One of the most difficult problems confronting the tool designer is the means for properly and securely holding the work. This difficulty most frequently

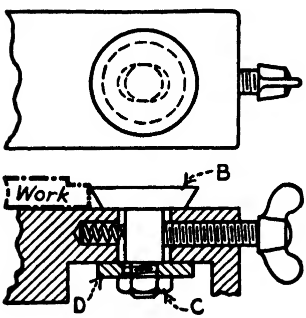


FIG. 177.

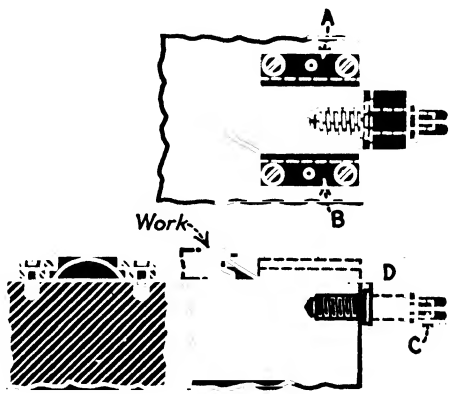


FIG. 178.

FIGS. 177–178.—Two simple clamping devices.

arises when the part has no projection or lugs, so that it is impossible to use clamps.

The illustrations are shown to assist the tool designer or toolmaker when in want of schemes for holding such work as plates and covers to be milled, profiled, disk-ground, etc.

A cheap, efficient, and quickly made work-holding device is shown in Fig. 177. The whole thing may be made on a lathe. The body *B* should be made of tool steel and properly hardened and ground. Care should be given the hardening, as the sharp corner which is continually coming in contact with the hard, scaly casting, if too hard, breaks. The body is held in position by the nut *C* and washer *D* and should be a sliding fit in the support or body in which it works. A stiff spring should be inserted to act as a release. This scheme is excellent for holding light

aluminum castings, and the construction prevents the chips from interfering with its movement.

A single point guided by the two gibs *A* and *B* and operated by the screw *C* is shown in Fig. 178. This screw controls the clamping and releasing movement of the nipping block *D* and does away with a spring which would otherwise have to be added to make the design correct. The screw should be placed as near to the center line of thrust as possible. This will reduce the clamping action on the nipping block which is the only fault in this design.

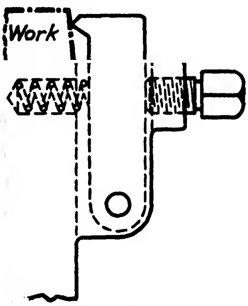


Fig. 179.

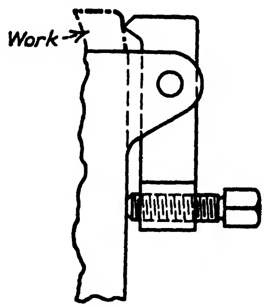


Fig. 180.

Figs. 179–180.—Two forms of toe clamp.

Both Figs. 179 and 180 are very much alike. Figure 179 is frequently used when heavy work is to be done, and Fig. 180 when light milling or profiling is required. Both are called toe clamps.

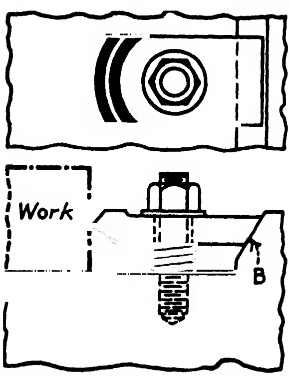


Fig. 181.—A clamp for heavy cuts.

The clamp shown in Fig. 181 is used when the part that it is to hold has to undergo a heavy cutting operation. When pressure is applied to the clamp, it has a tendency to force the part not only down but also ahead. An objection to this style of clamp arises when the designer makes too slight a taper at *B*; this causes the clamp to bind between the work and taper. The taper should not be less than 30 deg., and a stiff spring should be added beneath the clamp.

Other Arrangements of Nipping Blocks.—There is a similarity between Figs. 182 and 183, the only difference being the nipping

blocks *A*. In Fig. 182, the work rests on the nipping block *A*, which acts as a support for the work and, therefore, does away with the pin *B* in Fig. 183, on which the work rests in this figure. Both of these designs are used to good advantage on profiling or milling fixtures, especially when the work is large and of irregular shape such as aluminum crankcase basins, splash pans, and gear-case covers.

The nipping blocks should be a nice sliding fit, and the pressure clamp *C* should be slightly rounded at the point of contact, so as to insure a perfect seat when the pressure is applied. Means

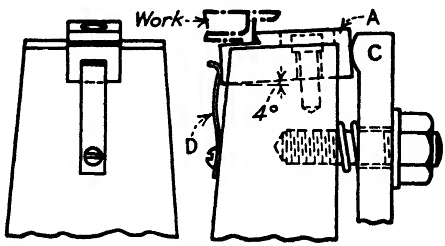


FIG. 182.

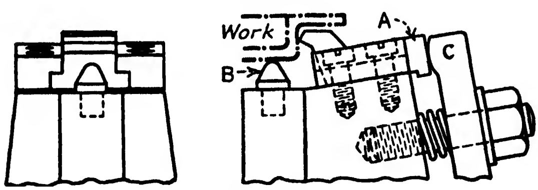


FIG. 183.

FIGS. 182–183.—Clamps for light work.

should be provided to prevent the clamps from turning, so that when the nuts are being tightened upon them, they will stay in position. There should also be some provision similar to the flat spring *D* for forcing the nipping blocks back to their original position, as shown at *D* (Fig. 182). There are many ways in which this can be done, but the best method is generally governed by the design of the fixtures.

Figure 184 shows a double clamp which pulls the work down on the center anvil from both sides. The jaws bite the work, and the angle at the lower end of the clamps draws them down.

Quick-operating Fixture Clamps.—It was required to design a milling fixture for holding a frail casting, which had to have a number of cuts taken at different settings; and as the work must

be accurate, it had to be held so that the mills or clamps would not spring it. It required a number of clamps and stops and had to be put in and taken out a number of times, so it was necessary to have the clamping and releasing operations consume as little time as possible.

A method for holding down one end of the casting *B*, which rests on a hardened pin driven in the fixture *A*, is shown in Fig. 185. The clamp *C* bears at three points, one on the work and two at the opposite end. It has an ordinary elongated slot so that it can slide on and off the work without hindrance by the binder stud. A spring lifts it from the

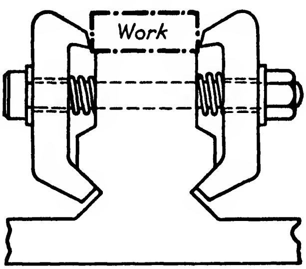


Fig. 184.

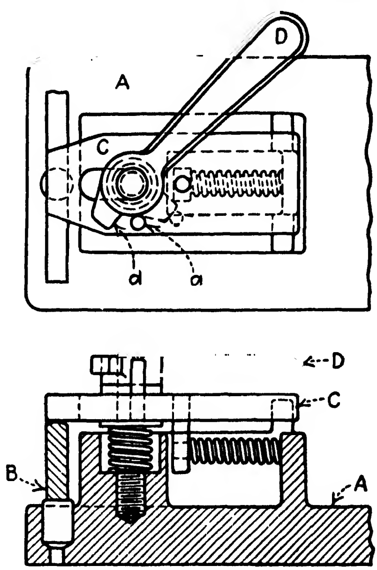


Fig. 185.

Fig. 184.—Double-clamp block with wedging action.
Fig. 185.—Quick-acting clamp.

work when it is released by the binder *D*, which is tapped to fit a stud that is screwed into the fixture.

The projection *d* on the binder is so located that when it is turned enough to release the clamp it comes in contact with the pin *a*, which is tight in the clamp, and forces the clamp off the work. When it has turned far enough (as shown by the dotted lines), it will lock and stay so until ready to clamp another piece. When the binder is moved to clamp the work, the spring shown under the side in a horizontal position forces the clamp into place before the binder has secured it, so that the simple movement of the binder is all that is necessary for securing and releasing the piece; thus the usual extra movements in sliding the clamp on and off the work are avoided.

Cam-shaped Clamps.—Three clamps are used for holding the work down in the fixture shown in Fig. 186. Hardened pins give three points for the work to rest on. In connection with these, there are, at different places under the work, the common pin with a spring under it to force it up to the work and a setscrew to bind and hold it from moving when the cut is taken.

In Fig. 186, *E* is a hollow casting fastened to the fixture by screws. The clamp *F* on the inside and the lever *G* and the cam

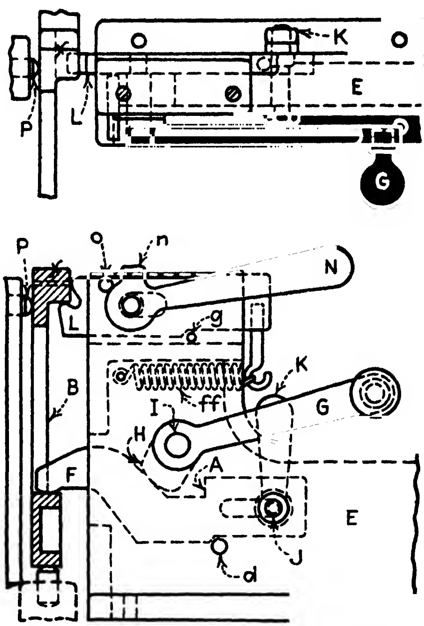


Fig 186.—Using cams for clamping.

H on the shaft *I* bind the work *B*. At *J* is a shaft which supports the clamp and is made eccentric where the clamp rests; this allows the operator to adjust it to conform to the variations in the castings by turning it with the handle *K*, although this needs very little attention.

In operating the lever *G* when releasing the clamp, the cam *H*, which is inside the casting, comes in contact with the projection at *A* on the clamp and forces it off the work; and as it strikes the pin *d*, it rises and stays in its elevated position until it has again passed on to the work where clamping. In operating the lever *G* for

clamping, the cam H forces the clamp into position and secures it with the single movement.

The top of the casting has to be finished at two places on both sides. Two supports like L are used, which are carried by the casting E and are secured by the binders N. In operating the binders to release the supports, the projection n comes in contact with the pin o, which is driven into the casting E. This forces the binder and support away from the work, the stud in the binder sliding in a slot in the casting; when it has moved far enough, it will lock under the tension of the spring ff.

As the support moves, it strikes the pin g, and this compels the end that comes in contact with the work to drop and stay down until it is moved into position for clamping and has passed under the work. When the binder N is operated for clamping, and the projection n has passed the pin o, the spring ff forces the support into place and compels it to seat at both points, before the binder secures it.

Design of Cam Locks.—Cam locks are frequently used in fixture designing. If the amount of rise is too rapid, the work of locking is increased, and the locking action is not so secure. If the rise is too small, too great accuracy is necessary in machining, and the locking movement may not be sufficient.

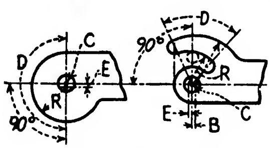


FIG. 187.—Two types of cam locks.

Two types of cam locks are shown in Fig. 187. Below is the formula used for calculating the rise and the method of laying them out. It is considered good practice to have a rise of 0.001 in. for every degree of arc at a radius of 1 in. This makes the total eccentricity equal 0.001 in. times radius of the arc times the number of degrees to be used, which usually runs from 60 to 90 deg.

The amount of eccentricity, or cam action, is increased with the radius, as the surface of the cam lengthens the farther it is away from the center. In simplified language, the rise of the cam is 0.001 in. for each degree of movement for each inch of radius. Or a 60-deg. movement on a cam of 2 in. radius will have a rise of 60 times 0.002, or 0.120 in., nearly ⅛ in. In making such cams, a tolerance of from 0.005 to 0.010 in. should be maintained. In laying out such cams, convert the distance E into the nearest fraction of an inch. Scribe the radius R for an inside cam, and

lay off an outside cam from the center at *B*. The illustration at the left shows simply an outside cam, such as is used in locking a latch in place.

Quick-operating Spring Pins.—On one side of these supports is a pin *B* which is driven in a lug cast on the fixture. On the opposite side is one like the pin shown in Fig. 188. This is necessary in order to take care of the variations in the castings. At one point, it was necessary to hold it sidewise only, but, as it had been

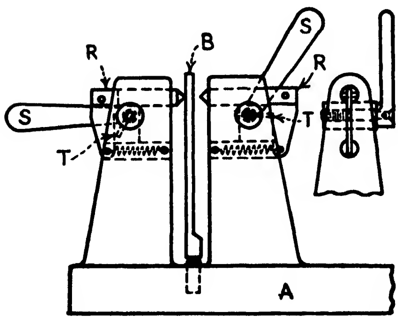


Fig. 188.

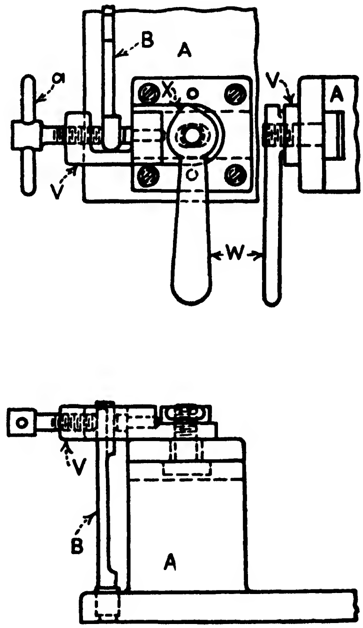


Fig. 189.

Figs. 188–189.—These show the use of quick-operating spring pins.

located and secured by other clamps, it was necessary to have floating stops so that they would conform to the casting; these are shown in Fig. 188.

Two lugs were cast on the fixture, and the pins *R* fitted to slide freely. The pins were provided with arms extending down to allow springs to be connected to pull them against the work. One of these is shown in clamping position, and the other drawn away from the work. The binding levers *S* are fitted to studs with one end threaded and fitted to nuts. On the opposite side of the pin *R* from the nut is a collar or bushing; this collar and the nut are

shaped to fit the pin and hold it firmly when clamped by the levers S.

Driven into each of the studs is a pin *T*. This is so located that when the lever *S* is removed in unclamping, it strikes the arm and forces the pin *R* away from the work and holds it thus until the binder is operated again for clamping.

There were two parts of the casting where the cuts were quite heavy, and the clamps had to adjust themselves to the work as others in clamping located it. Figure 189 shows the design used. Lugs were cast on the fixture, and on top were fitted caps for

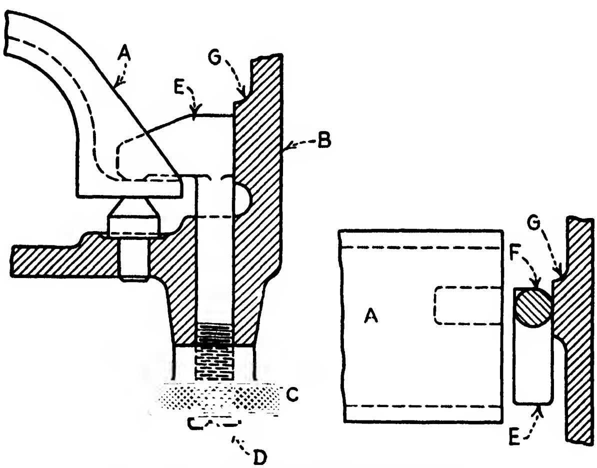


FIG. 190.—Clamping against a button.

supporting the clamps. One of these clamps is shown at *V*. The clamp in this case had to swing around out of the way to facilitate putting the work in and out.

The binder *W* is fitted to a stud which passes through an elongated hole in the cap and has a square head which fits freely in a slot planed in the top of the lug. This prevents it from turning when the binder *W* is operated. The clamp screws *a* and the binders are made with right- and left-hand threads and are operated both at the same time, one with each hand. The clamps are turned around in position, and the screws *a* set up; then with the binders they are secured to the caps which hold the casting so that it cannot move. When releasing them, the screws *a* are loosened first so that when the binders are operated the projection

X strikes the clamp and turns it out of the way with the same operation.

A Handy Jig Clamp.—The jig clamp in Fig. 190 shows a style that can be used in close quarters or when a quick-release motion is desired. The casting *A* is ribbed at the top and bottom, and being a trunnion jig it was desirable to have the slide *B* free from the clamp. To remove the casting, a couple of turns on the knurled knob *C* brings it against the washer *D*, and a quarter turn more throws the clamp *E* to its side position, thus allowing

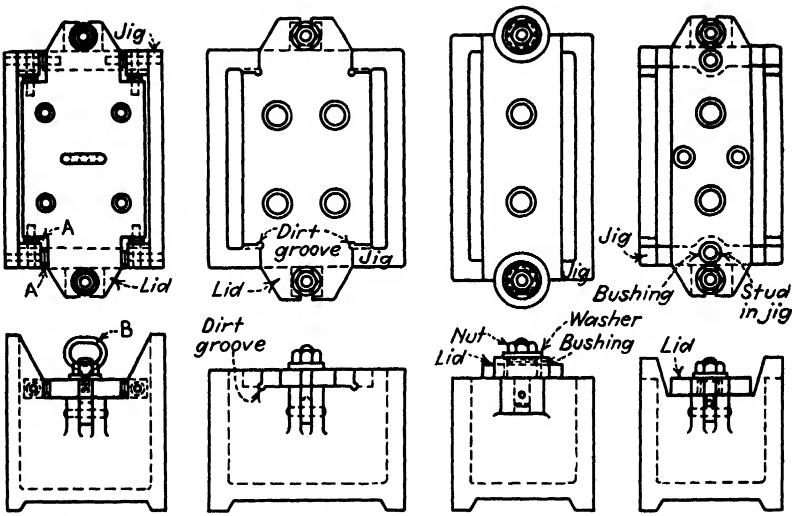


Fig. 191. Fig. 192. Fig. 193. Fig. 194.

Figs. 191–194.—Design of drill-jig lids.

the work to be removed. When clamping the work, the friction of the knurled knob against the washer causes the clamp *E* to return to its horizontal position until the side *F* strikes the finished pad *G*, and further turning the knob clamps the work.

Drill-jig Lids.—Drill-jig lids may be divided into two classes, removable and swinging. There are a great many ways of designing them, and many points in this construction are too often overlooked. Some of the details that should be considered in this connection are given herewith.

Figures 191 to 194 are good examples of everyday practice in designing or making removable lids. Figures 191 and 192 are very similar. Where extreme accuracy is to be maintained for a

very great length of time, Fig. 191 answers nicely. Hardened plugs are driven in the jig body and lid at A. They accurately locate the lid as well as prevent wear.

On large jigs, convenient means should be provided for removing the lid without imposing too much labor on the operator, as this slows the work and seriously affects production. In some instances, an eyebolt *B* is provided, as shown in the illustration, to permit the use of hoist or other lifting mechanism.

The Dirt Groove.—In Fig. 192 will be found the general practice. Attention here is called to the dirt groove, which is so often overlooked; it will be found of advantage to rib these lids whenever possible, on either top or bottom.

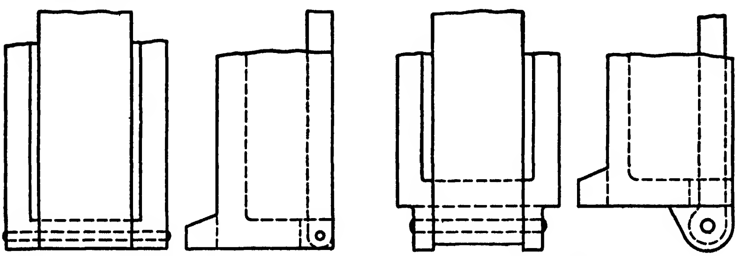


FIG. 195. FIG. 196.

FIGS. 195–196.—Swinging drill-jig lids.

Figures 193 and 195 are very much alike. In Fig. 193, the stud is made large enough to allow the lid to be removed without taking off the nut. The nut is simply loosened, and the slip washer removed. In Fig. 194, the lid is located by means of the two studs similar to Fig. 193, but, to remove the lid, the two end-bolts are released and swung out of the way. It is always advisable to harden the studs in both cases and provide hardened bushings in the lid for them to work into. Do not make the studs any longer than is absolutely necessary, as the longer the studs the more difficult the operation of removing the lid.

Figures 195 to 202 show a few examples of swinging lids. Figure 197 is an improvement over Fig. 195, on account of the hardened-steel bushings. Its wearing qualities are doubled, and its accuracy maintained.

Figure 198 is an improvement over Fig. 196 and is probably the most commonly used.

Figure 199 illustrates a method of securing the opposite end of a swinging lid and takes the place of the eyebolt, as shown in Fig.

200. Hardened-steel bushings are placed in the jig body and in the lid. The pin, being a sliding fit, holds the lid properly. Attention may be called to the designing of the lug in the upper

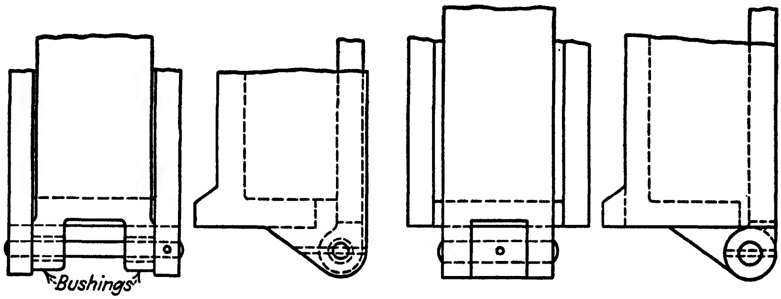


FIG. 197. FIG. 198.

FIGS. 197–198.—Different designs of pin bearings.

view of Fig. 200. The lug acts as a support for the bolt and seat for the lid. In this construction, there is no danger of the lid being broken or sprung out of shape in case the operator puts an excessive amount of strain on the bolt.

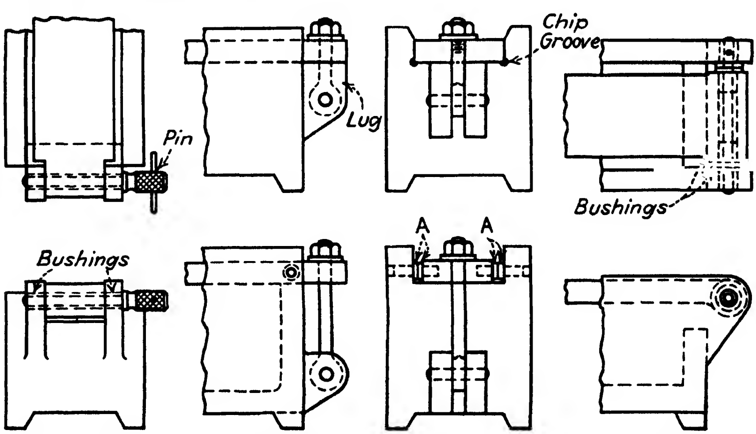


FIG. 199. FIG. 200. FIG. 201. FIG. 202.

FIGS. 199–202.—More details of drill-jig lids.

Figure 201 is made similar to Fig. 191, having the inserted studs *A* for keeping the lid in alignment and also increasing its wearing qualities.

Figure 202 is an improvement over 197. The bushings are so designed to take up the wear on the pin as well as the sides of the

lid. This design is expensive and used only where continued accuracy is required.

ADDITIONAL CLAMPING METHODS

The accompanying illustrations show various clamping methods used for many purposes. They include the use of beveled sur-

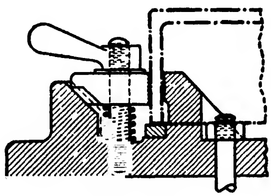


Fig. 203.

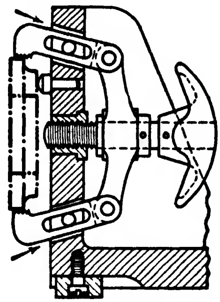


Fig. 204.

Fig. 203.—Clamping a thin side wall.
Fig. 204.—Centering work with toggle jaws.

faces, toggles, cams, screws, and a variety of lever combinations. Each has been found useful in some design and may have advantages under proper conditions. In general, these which tend to pull or force the work against the seat, or locating surfaces, usually have the advantages.

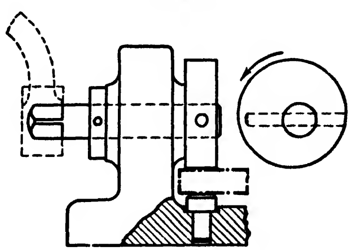


Fig. 205.

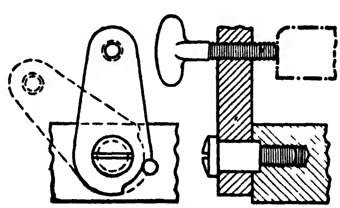


Fig. 206.

Fig. 205.—Cam bears directly on work.
Fig. 206.—Simple swinging clamp screw.

These devices seem to require little detailed explanation, as a study of the illustrations indicates the way in which each operates. Suitable applications will occur to each designer as occasion arises. The captions explain the illustrations (Figs. 203 to 209 inclusive).

Fixture with Equalizing Clamps.—The illustration Fig. 210 shows a fixture for holding work while the two opposite edges are being milled. The main feature of the fixture is that both clamps are tightened by one screw *A* and that the pressure upon the work is equal at each end.

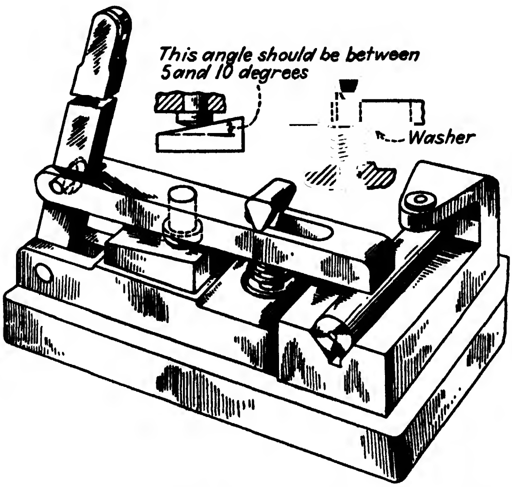


Fig. 207.—Holding work by wedge under the clamp arm.

Directly under the clamping screw is a sliding plug which contacts with both the screw and the equalizing lever *B*. At the other end of the fixture is the sliding plug *C*, acted upon by that end of the equalizing lever. When the clamping screw is tight-

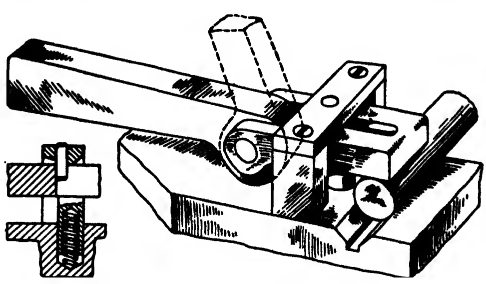


Fig. 208.—Quick-acting cam lever clamp.

ened, it forces down the plug under it, depressing that end of the lever. Depressing the left-hand end of the equalizing lever raises its right-hand end and forces up the plug *C*. It will be seen that the pressure exerted by the screw will cause the heel of the

clamp at the left to rise and that this pressure transmitted through the equalizing lever and the plug *C* will have the same effect upon the heel of the clamp at the right. As both clamps are pivoted upon pins, raising their heels forces their toes down upon the work.

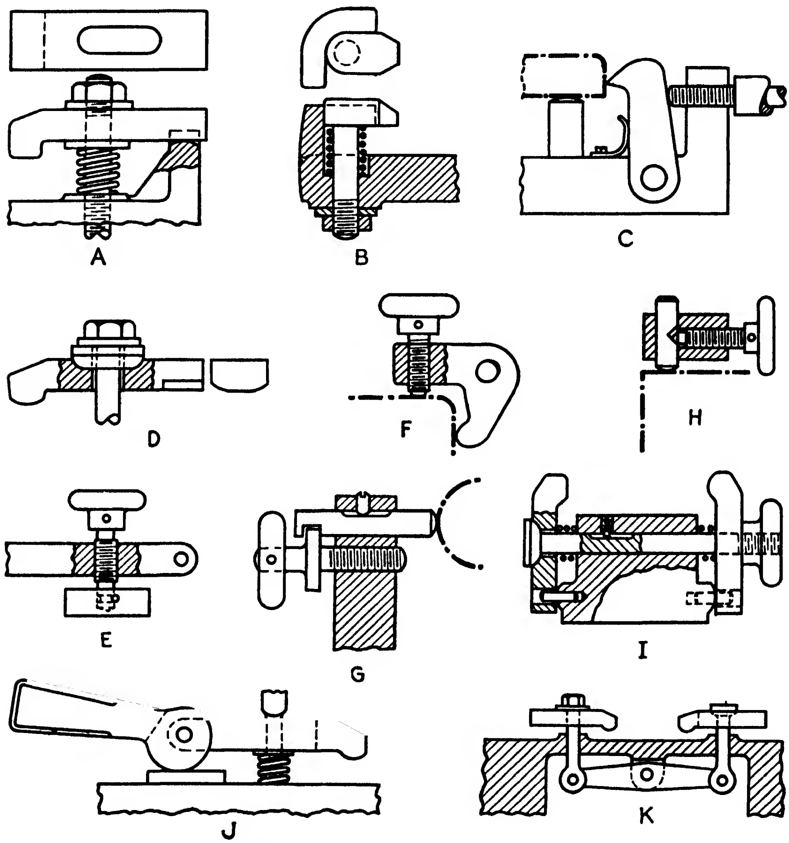


FIG. 209.—A—Plain-type clamp. B—Hook bolt. C—Knife-edge clamp. D—Clamp with rocking action. E—Clamp with swivel contact. F—Double-acting clamp. G—Clamp to avoid twisting action. H—Useful type of jig-leaf clamp. I—Double-type clamp. J—Cam-operated clamp. K—Double-equalizing clamp.

Both clamps are slotted where they bear upon their pivot pins, allowing them to be slid endwise on and off the work. The clamp at the right is provided with a lever for ease of movement. When this clamp is off the work, the clamp at the left is, of course, loose enough to be moved by the fingers. In moving the clamp at

the left, the length of its slot does not permit the clamping screw to come out of the line of contact with the plug beneath it.

Quick-acting Clamps.—A swinging clamp for use where the work is placed over a locating pin or where there is not room to

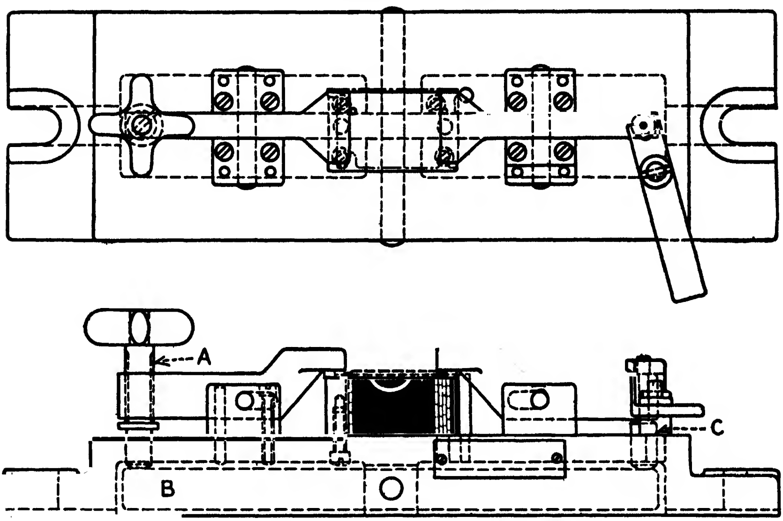


FIG. 210.—Clamps which equalize pressure.

operate a sliding clamp is shown in Fig. 211. The clamp is pivoted at *A*, and in the underside of the wing nut *B* is a concentric slot terminating at one end in a short radial slot. A small pin in the clamp engages this slot.

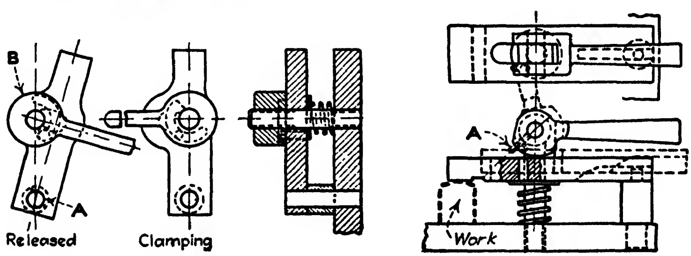


FIG. 211. FIG. 212.

FIGS. 211–212.—Two quick-acting clamps.

By rotating the wing nut to the right, the clamp will be swung into clamping position by the pin *A* engaging the radial slot. Continued rotation of the wing nut will bring the clamp down on the work. Rotating the wing nut in the opposite direction will

release the clamp and swing it into the released position. This clamp should not be used on work having a variation in thickness greater than one-half the lead of the thread on the bolt.

A cam-operated sliding clamp is shown in Fig. 212. When the cam is rotated to the left, the first few degrees of rotation will release the work. Continued rotation will cause the pin *A* to engage a hole in the clamp and slide the clamp to the right, clearing the work. If the cam is rotated to the right, the pin *A* will again engage the hole in the clamp, moving the clamp to the left and over the work. Further rotation of the cam will bring the toe of the clamp down on the work and hold it securely.

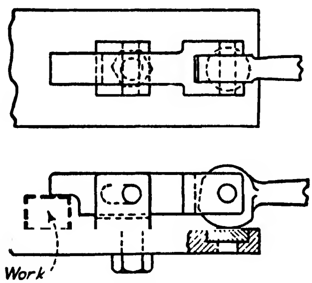


Fig. 213.

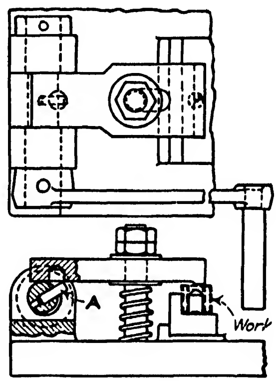


Fig. 214.

Figs. 213–214.- Clamps that save operating time.

Another cam-operated sliding clamp is illustrated in Fig. 213. The cam is at the heel of the clamp and bears on a hardened insert. In this clamp, the cam is used only for clamping the work, the sliding being done by the operator.

The clamp in Fig. 214 is operated by an eccentric under its heel. When the eccentric is rotated to the left, the heel of the clamp is lowered, and the toe raised, releasing the pressure on the work. On further rotation of the eccentric, the pin *A* in the eccentric engages a hole in the clamp and slides the clamp to the left, clearing the work. Rotating the eccentric in the opposite direction will slide the clamp over the work.

Uses and Advantages of the Latch Jig.—Of all the special tools used in a modern manufacturing establishment for the economical production of a large number of small parts, no tool offers in its

scope a wider adaptability for the rapid production of interchangeable parts than the latch jig.

It is simple in construction, capable of producing uniformly accurate work, designed to withstand rough usage, rapid and easy of manipulation, easily cleaned, and accessible when handling the work.

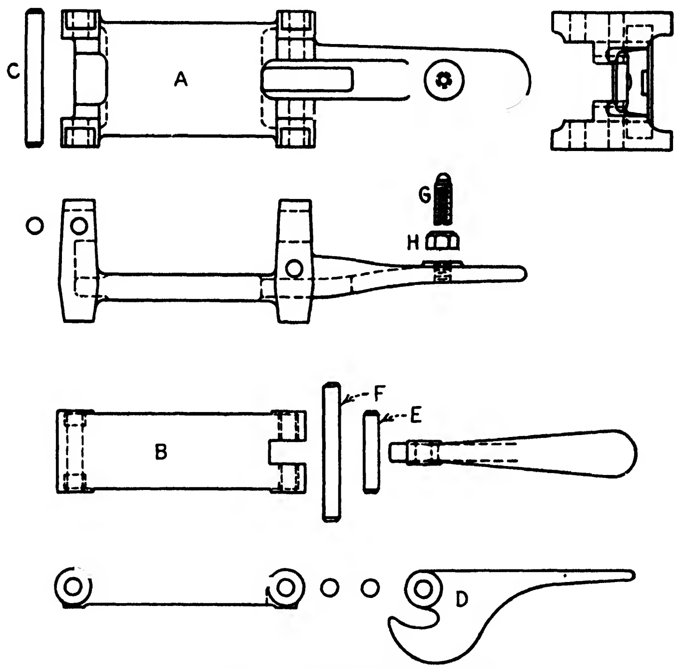


FIG. 215.—Parts for a latch jig.

All of these essentials are embodied in this particular type of tool. One movement is sufficient to open it and expose its gage points and nest. It is easily and quickly cleaned. It is conveniently and quickly loaded. It is simple in its construction, hence capable of withstanding rough usage and still maintaining its accuracy. One movement, and the cover is closed, and the work clamped securely in position. Speed, the most desirable feature of a good tool, makes the quick-acting latch jig a most desirable factor in good tool design.

Referring to Fig. 215, the component parts of this tool may be enumerated as follows: *A*, frame; *B*, cover; *C*, cover hinge pin;

D, latch; *E*, latch hinge pin; *F*, latch fulcrum pin; *G*, latch stop screw; *H*, latch stop-screw nut.

It is not feasible to use a latch jig on work that varies greatly in thickness, such as rough castings and rough forgings, without

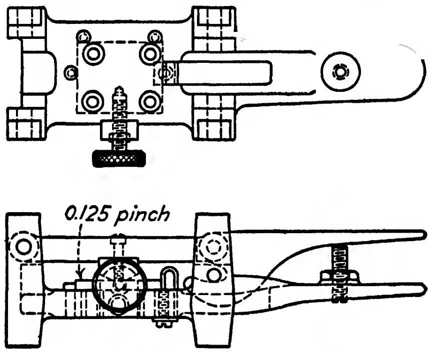


FIG. 216.—A simple latch jig.

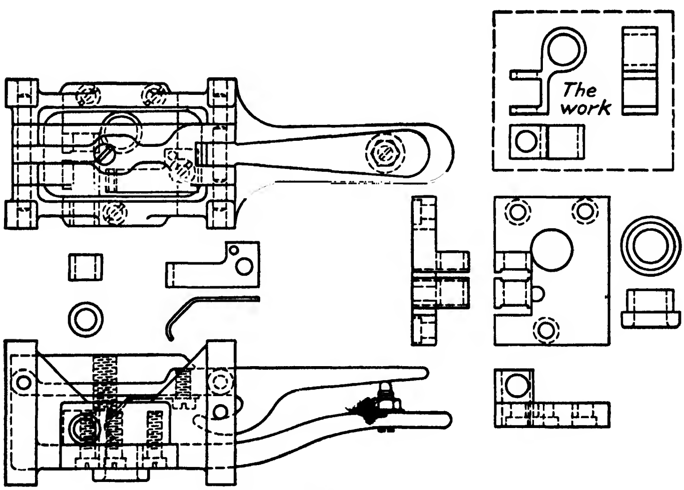


FIG. 217.—Box type of latch jig.

providing a compensating device on the cover. This is due to the fact that the cam on the latch is short and provides approximately 0.03 in. for variation in the thickness of the work.

Generally speaking, there are three styles of this type of jig, and they may be designated as follows: the open type, the box type,

and the reverse type. The open type, with handle and latch projecting, as illustrated in Fig. 216 is particularly recommended for flat work, which requires plenty of finger room. The gage points and nest are conveniently located. This type is recommended where holes are to be drilled and reamed at right angles with the side of the work only.

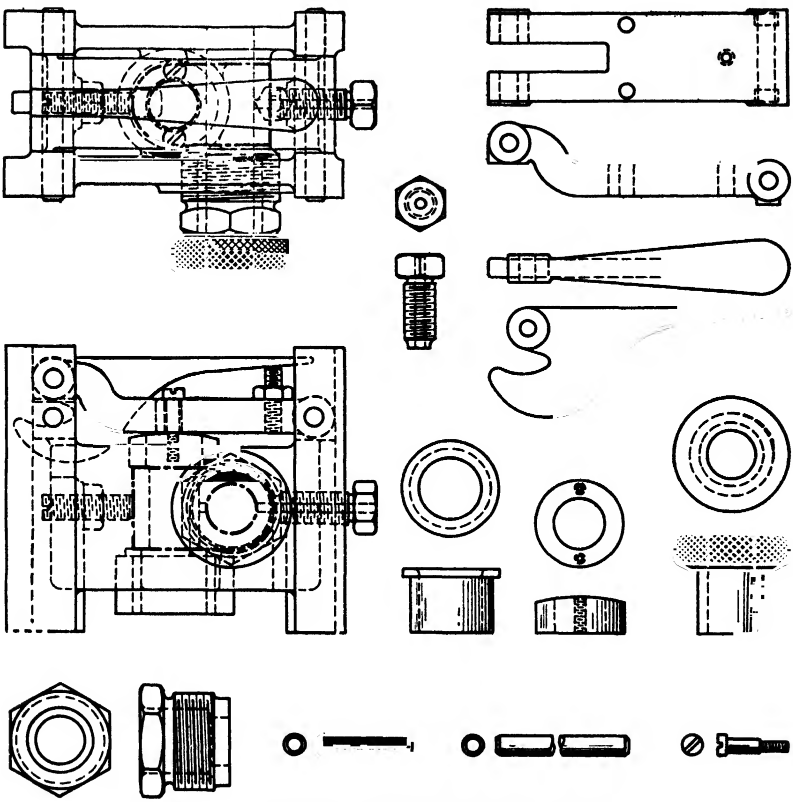


FIG. 218.—Here the latch swings inside the jig.

When the parts to be drilled are of uniform thickness, if so desired the bushings may be located in the cover. It is good practice to do this whenever possible, as it dispenses with the necessity of turning the jig over when preparing for the actual operation of drilling.

If the work varies considerably in thickness, the cover may be clamped on a finished seat on the body, and a binding screw

added to the cover for clamping the work. By this method, the center line of the bushing will be presented at right angles with the nest or gage seat which receives the work.

In addition to the open type, an illustration is given in Fig. 217 of the inclosed, or box, type, which permits the use of bushings in the sides as well as in the cover and bottom. This jig is capable of accommodating a diversified line of parts with very satisfactory results.

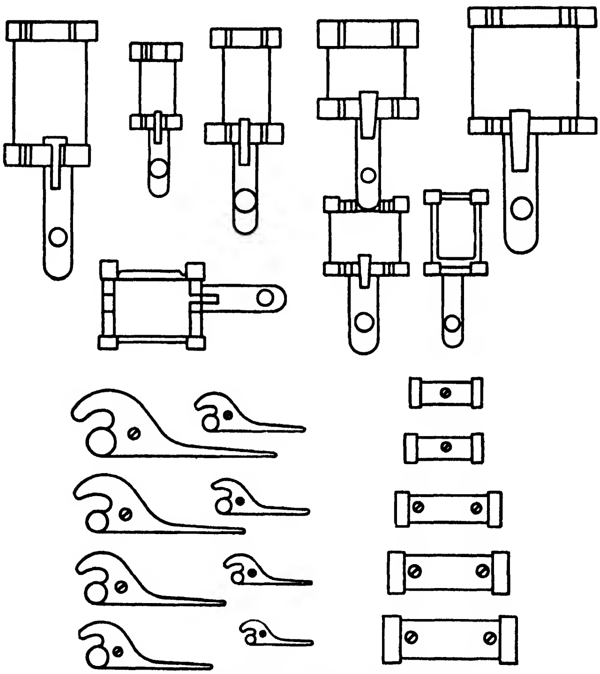


Fig. 219.—Stock parts for latch jigs.

Frequently it is necessary to drill a part from five sides. To do this, a very ingenious arrangement is used, as in Fig. 218, whereby the handle is dispensed with and the latch is reversed to swing toward the center of the jig, using an offset cover to accomplish this purpose. This jig is capable of a very wide range of work and gives excellent results.

Stock Parts for Latch Jigs.—In the Taft-Pierce Mfg. Co.'s very elaborate and complete stock of standard jig, fixture, punch and die, and miscellaneous tool fittings are kept eight sizes of

jig frames and fittings in steel castings. These are being constantly used and adapted to the needs of the rapid and accurate production of parts for adding machines, typewriters, sewing machines, cash registers, parts for small automatic machinery, motorcycle motors, automobile parts, etc. These stock-jig parts are represented in Fig. 219, and a group of completed jigs is seen in Fig. 220.

Where large quantities of work are involved, it is good practice to make the frame of a steel casting and harden the feet. This is best accomplished by machining the body of the jig before boring

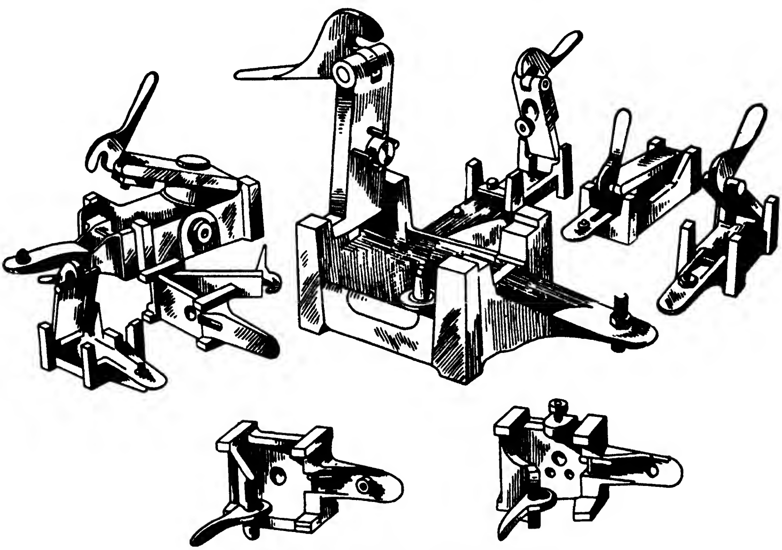


Fig. 220.—A group of latch jigs.

to receive the drill bushings. Drill the holes to receive the proper cover hinge pin and latch fulcrum pin; then pack the frame in an iron box, and cover the work with any of the carbonizing preparations. Seal the box to make it airtight, and heat the work in a hardening furnace to about 1500 to 1600°F. for a period of 6 to 8 hr., depending upon the size of the frame. Remove the box from the furnace, keep it sealed to exclude the air, and allow the work to cool in the box.

Next, heat the ends of the feet for a distance of about $\frac{3}{4}$ in. in the lead pot to a cherry red, and quench in cold water. Surface grind the legs, the feet, and the seats square with each other; then

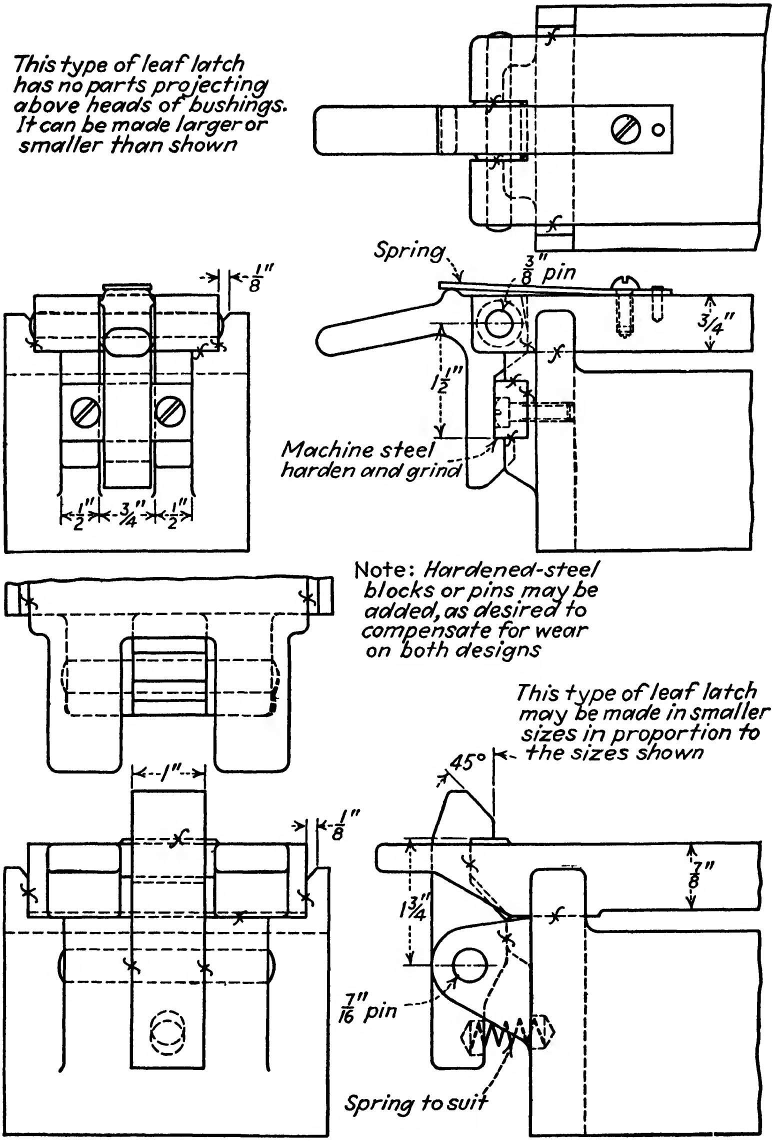


Fig. 221.—Details of a fast-working latch jig.

bore for the drill bushings, registering from the hardened and ground surfaces. By pursuing this method, an accurate and extremely durable jig is obtained.

Rapid-action Jig Latches.—One essential in the design of latch jigs is that they shall operate quickly. Clamps and bushing plates can be held firmly with nuts and bolts, but the latch jig can save much time in handling, if properly designed.

The illustrations in Fig. 221 give a number of designs and some of the main dimensions to show proportions. The surfaces that should be finish machined are shown by the usual mark *f*.

Clamp Bushings.—Such satisfactory results having been attained with clamp bushings, it is surprising that they are not

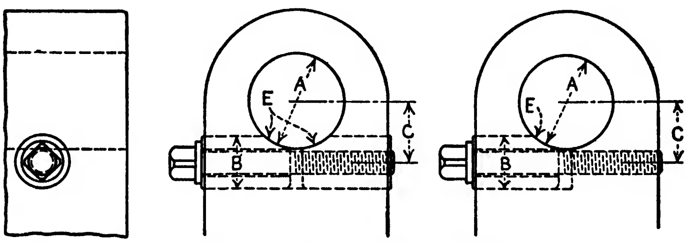


Fig. 222.—Designs of clamp bushings.

more extensively used in machine-tool work. This probably is due chiefly to the difficulties that are encountered in their manufacture.

A designer in the employ of a large machine toolmaker persuaded the authorities to experiment with clamp bushings of the design shown in Fig. 222. The experiment being successful, the bushings were incorporated in a new design of machine, and the first order was for 1,000 of four different sizes.

It was debated whether these could be stocked as standard parts, as the surfaces *E* would have to be machined with the bore *A*. The holes *A* and *B* were both to be bored at one setting in a jig, and as they could rely on the dimension *C* being held, it was decided to finish the clamp bushing right up, that is, by milling the surfaces *E* with a radius form cutter in a fixture made for this purpose. This proved much cheaper than boring them out with the hole *A*.

The results obtained were so satisfactory that it was decided to introduce a list of standard clamp bushings. They were tabu-

lated and made up in lots of 500 and put in stock. Both halves (in model 2, only the front half of the bushing is used, and the thread is tapped into the body of the piece) were made from

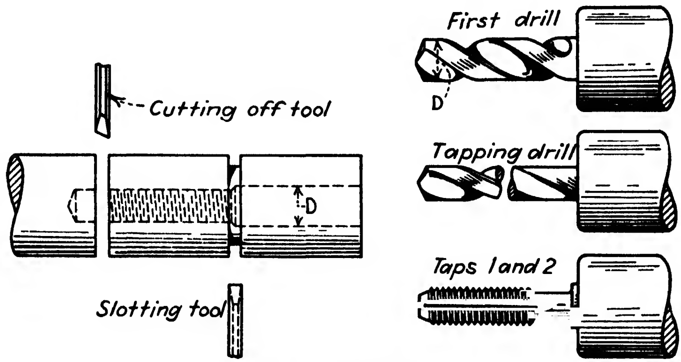


Fig. 223.—Tools for making clamp bushings.

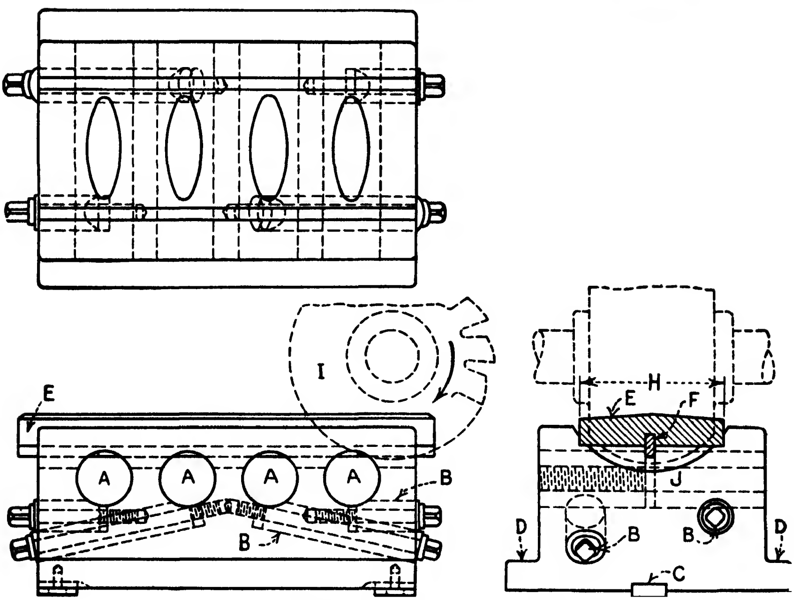


Fig. 224.—Fixture for milling the bushings.

ground stock, in one piece. They were slotted, drilled, tapped, and cut off on an automatic screw machine, as in Fig. 223.

The fixture for milling is seen in Fig. 224. Four pieces can be clamped, and the cutter run straight through. The pieces are a

nice fit in the holes *A* and are clamped by the bushings *B*. The body is made of cast iron, and the bushing of soft machine steel. The body is of rugged design with the tongue *C* to fit slots in the miller table; it is supplied with two edges *D*, to clamp the fixture to the table.

The long piece *E* with the tongue *F* is a nice fit on the dimension *H*. The tongue *F* is slightly thinner than the slot in the workpiece and lines up the pieces, insuring their centrality with the cutter.

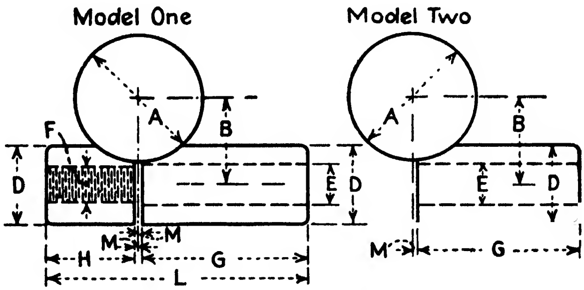


TABLE 1.—SIZES OF CLAMP BUSHINGS

Diam. to be clamped *A*	*B*	*D*	*E*	*F*	*G*	*H*	*L*	*M*
5/8	1/2	9/16	21/64	5/16–18	1/2 & 3/4	1/2	1 1/8 & 1 3/8	1/16
3/4	5/8	11/16	25/64	3/8–16	9/16 & 3/4	9/16	1 1/4 & 1 7/16	1/16
7/8	11/16	3/4	29/64	7/16–14	3/4 & 1 1/8	3/4	1 5/8 & 2	1/16
1	3/4	7/8	29/64	7/16–14	7/8 & 1 1/4	3/4	1 3/4 & 2 1/8	1/16
1 1/8	7/8	1	33/64	1/2–13	1 & 1 1/2	7/8	2 & 2 1/2	1/16
1 1/4	15/16	1 1/8	37/64	9/16–12	1 1/4 & 2	1	2 3/8 & 3 1/8	1/16
1 3/8	1 1/16	1 1/8	37/64	9/16–12	1 1/4 & 2	1	2 3/8 & 3 1/8	1/16
1 1/2	1 1/8	1 1/8	37/64	9/16–12	1 1/4 & 2	1	2 3/8 & 3 1/8	1/16
1 3/4	1 1/4	1 1/4	37/64	9/16–12	1 5/8 & 2 1/4	1 1/4	3 & 3 5/8	1/16
2	1 3/8	1 1/4	41/64	5/8–11	1 7/8 & 2 1/2	1 3/8	3 3/8 & 4	1/16
2 1/4	1 1/2	1 1/4	41/64	5/8–11	1 7/8 & 2 1/2	1 3/8	3 3/8 & 4	1/16
2 1/2	1 5/8	1 3/8	41/64	5/8–11	1 7/8 & 2 1/2	1 3/8	3 3/8 & 4	1/16
2 3/4	1 13/16	1 3/8	41/64	5/8–11	2 & 2 3/4	1 1/2	3 5/8 & 4 3/8	1/16
3	1 15/16	1 3/8	41/64	5/8–11	2 & 2 3/4	1 1/2	3 5/8 & 4 3/8	1/16
3 1/4	2 1/16	1 1/2	49/64	3/4–10	2 1/4 & 3	1 3/4	4 1/8 & 4 7/8	1/16
3 1/2	2 3/16	1 1/2	49/64	3/4–10	2 1/4 & 3	1 3/4	4 1/8 & 4 7/8	1/16
3 3/4	2 5/16	1 1/2	49/64	3/4–10	2 1/4 & 3	1 3/4	4 1/8 & 4 7/8	1/16
4	2 7/16	1 1/2	49/64	3/4–10	2 1/4 & 3	1 3/4	4 1/8 & 4 7/8	1/16

The piece E is removed before milling. The cutter is shown at I, and the workpiece at J.

One great feature of this fixture is that clamp bushing of the same diameter of different lengths were easily made (G and L, see table of sizes. No change was necessary on the fixture for the different lengths.

The two halves were cut in two, and the corners rounded on a simple cutting-off machine. The bushings are not hardened, as

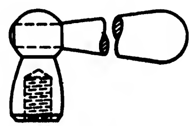


FIG. 225.

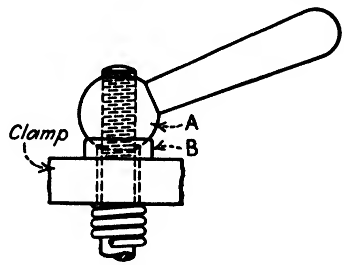


FIG. 226.

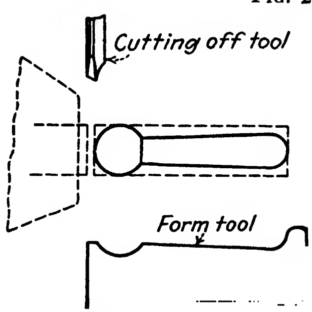


FIG. 227.

FIGS. 225–227.—Simple ball handles and tools for making them.

it was found that they clamp better when soft and are less likely to injure the piece being clamped. They are made from ordinary cold-rolled steel.

While the dimensions in Table 1 may not be found to suit all classes of work, they have been found satisfactory in general machine-tool design. In making model 2, two halves are made in one piece, as in model 1, but the hole D is drilled through both halves.

Clamp Nut and Handle for Jigs.—Time studies have shown that from $33\frac{1}{3}$ to 75 per cent of a workman's time is spent in clamping work in the jig. In many cases, it is impossible to use the same

hexagon- or square-head nuts throughout, and thus two or more wrenches are sometimes necessary. This is confusing to the workman, besides being a waste of time.

Many have tried to overcome this difficulty by making a special nut, like Fig. 225, with a handle and for which no wrench is required. This form of nut has been partially successful, inasmuch as it is easier to handle, but it has proved much more expensive than the ordinary hexagon nut.

A nut and handle *A*, made in one piece and used with a concave ball washer *B*, are shown in Fig. 226. This nut has proved very satisfactory and is not expensive to manufacture when made in quantities. It is inexpensive, inasmuch as it needs only one ball washer, whereas an ordinary nut when clamping rough castings or rough forgings needs a pair of washers, concave and convex.

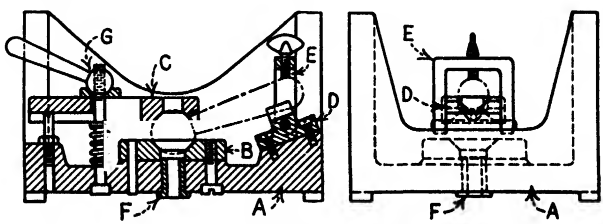


Fig. 228.—Drill jig for ball handle.

The nut and handle can be turned very simply on an automatic forming and cutoff machine with the tool shown in Fig. 227. It is then drilled in the jig (Fig. 228). It may be tapped in the jig, a removable bushing then being required, or in a separate tapping operation. The jig is of quite simple construction, the body *A* being of cast iron, and the centering plate *B* of hardened tool steel. The clamp *C*, of machine steel, is tightened with one of these nuts and the washers *G*. Here is seen a good example of the use of the nut with the concave washer, as it will be noted that in operation it would be much more rapid than a hexagon nut. The V block *D* and the latch *E* with a thumbscrew hold the handle of the piece at the proper angle. After tapping, the nut is complete.

Three jigs can be arranged to accommodate all these sizes. Of course, in that case the drill bushings *F* would have to be interchangeable.

Drill Jig for Ball Rods.—Having a considerable number of ball-ended bars to drill through the center of their knobs, the jig

shown in Fig. 229 was designed to meet the case. The knobs vary in diameter from 2½ down to 1 in., and the length of the bars varied in a corresponding manner. The problem was not a very difficult one, but it is not always easy to hit immediately on the best way of performing such an operation.

The ball end of the bar is placed in a fixed inverted cone *A*, and the other end is held in a similar though smaller inverted cone *B*,

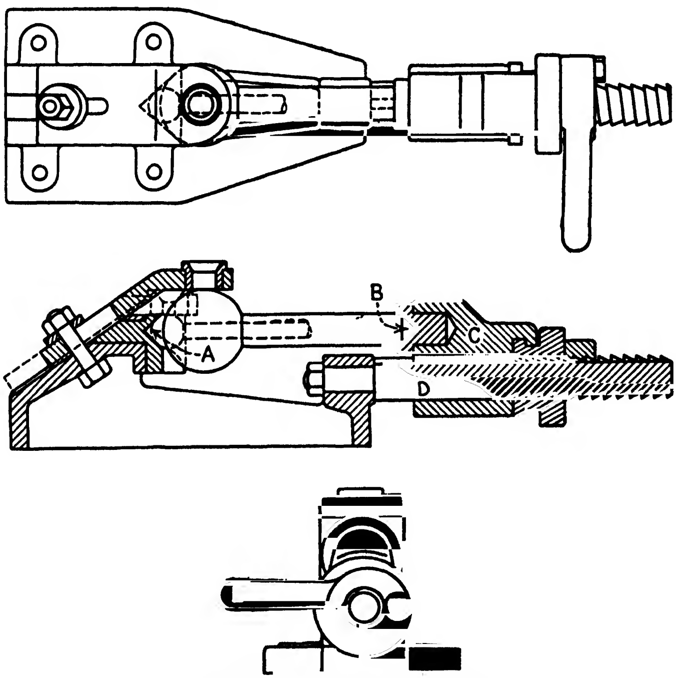


FIG. 229.—Jig for ball-end rod.

fixed in a block *C*, which slides on a screw *D*. The action of these two cones, when clamped, is to bring the axis of the bar to be operated on always into one position, whatever may be the size of the bar or its knob.

One of the novel points of the jig is the method of quickly applying pressure to this block so as to clamp the bar to be drilled firmly between the two inverted cones.

The block *C* is a sliding fit on the screw *D* and feathered to it so as to keep it upright. The lever *E*, hinged behind the block *C* to a collar and traveling with it, is formed into a part nut. When it

is desired to apply locking pressure to the bar through the block C, the part nut on the lever E is brought into mesh with the screw and screwed up as though it were a simple nut, thus tightening and clamping it. To release the bar, the lever is eased off, swung out of the way, and the block C slipped back.

The other difficulty involved was to make a movable drill bush to guide the drill that it may pass through a diameter of the knob of the work. This was done by means of the sliding bracket which is fastened on an inclined slide at 35¼ deg. This angle will bring the drill-guide bush to the right height above the work when it reaches the central position of the ball of any size whatever. It now remains only to graduate this sliding block for each size of knob, and the jig is complete.

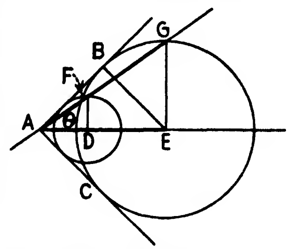


FIG. 230.—Laying out the angle.

Some will be interested to learn how the angle of 35¼ deg. is obtained, although it is only a simple geometrical problem solved by the aid of elementary trigonometry, as in Fig. 230.

Draw two lines AB, AC at right angles to each other to represent the inverted cone. Within this angle and touching each side of it, draw two circles of different size, with centers D and E to represent the ball ends of the rods. From D and E draw radii at right angles to AE, cutting the circles at F and G, respectively; and from E draw a radius at right angles to AB, cutting AB at B. Join G to F, and produce it, when it will be found to pass through the point A. Then the angle GAE, or Θ, is the angle required.

Now, the triangle ABE is a right-angled isosceles triangle, and therefore, if BE (the radius of the circle BGC) is taken as unity, the side AE is equal to $\sqrt{2}$.

Now, in triangle AGE, the side GE equals 1, and AE equals $\sqrt{2}$. But

$$\tan \Theta = \frac{GE}{AE} = \frac{1}{\sqrt{2}} = 0.707.$$

Therefore, $\Theta = 35$ deg. 16 min.

Even if the amount of work should require more than one jig it is convenient to be able to handle several sizes in one jig. One or two jigs can then be kept for the most used sizes.

CHART FOR DIMENSIONING STRAP CLAMPS

In designing strap clamps, Paul H. Winter, Chief Engineer, La Salle Engineering Company, finds it desirable to make the stud and the strap of approximately equal strength. A convenient way of doing this is to make the strap width equal to the diameter of the U. S. standard washer used with the stud, and

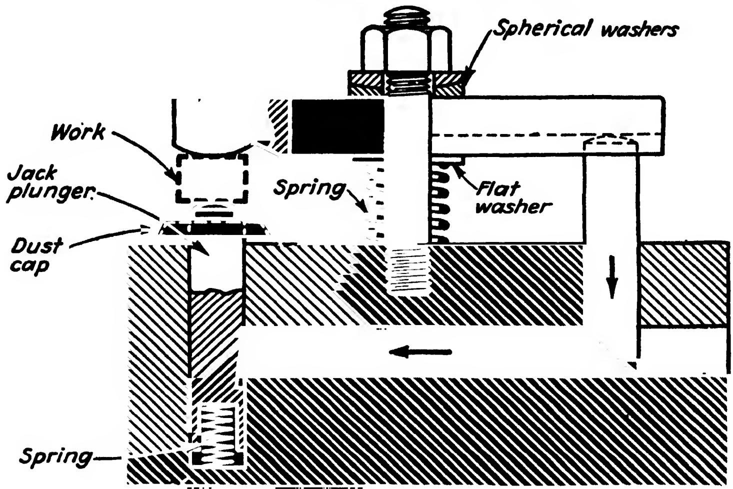


FIG. 231.—An equalizing clamp assembly.

TABLE 2.—STUD SIZE SELECTION

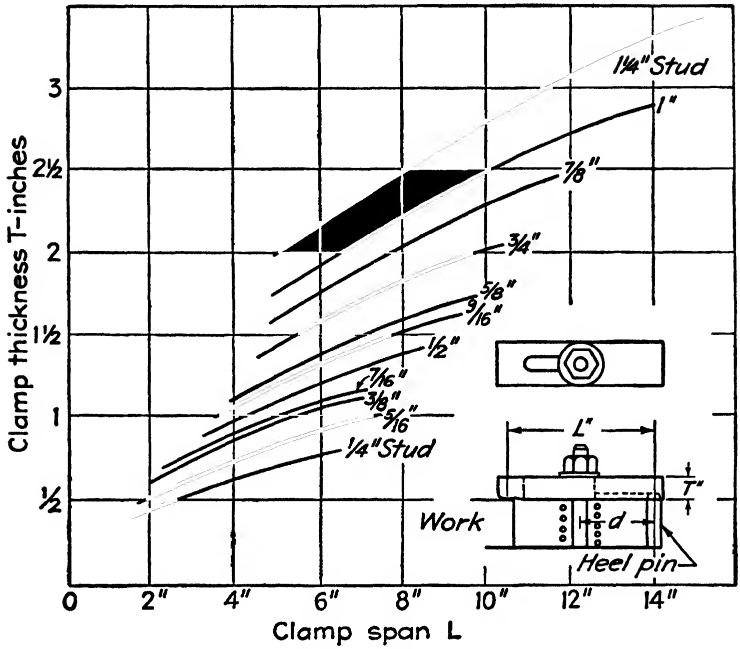
Clamping Pressure Required, Lb.	Stud Size NC Thread	Clamping Pressure Required, Lb.	Stud Size NC Thread
Under 100	1/4 —20	650–800	5/8 —11
110–185	5/16—18	800–1,200	3/4 —10
185–275	3/8 —16	1,200–1,675	7/8 — 9
275–375	7/16—14	1,675–2,250	1 — 8
375–500	1/2 —13	2,250–3,550	1 1/4 — 7
500–650	9/16—12		

then to select a strap thickness T suitable to the span L between the clamping point and the heel pin.

The chart with Table 3 was calculated for the condition where the stud is centrally located in the clamp and the slot is made with a standard end mill one size larger than the stud. To use the chart, first select the proper stud size for the clamping pressure (see Table 2). This is based on a fiber stress of 8,000 p.s.i. in the stud, giving an ample safety factor.

Example: Clamping pressure 400 lb.; stud size, 1/2—13 NC; span, 8 in. By reading up from span L = 8 on chart to curve for 1/2-in. stud and thence

TABLE 3.—STRAP FOR PROPORTING STRAP CLAMPS



CLAMP DIMENSIONS											
STUD	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1	1¼
SLOT	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1	1⅛	1½
WIDTH	¾	⅞	1	1¼	1⅜	1½	1¾	2	2¼	2½	3

left, it is seen that a thickness of 1⅜ in. is required. Ordinarily, the thickness is read to the nearest ¼ in.

If the stud is offset from the clamp center line, the stud size and the thickness of the clamp will be affected. To select the proper stud size use the formula:

$$P_o = P \times \frac{L}{2d}$$

where P_0 = equivalent pressure for use with chart to determine stud diameter,

P = actual clamping pressure,

L = actual span,

d = distance from stud to heel pin.

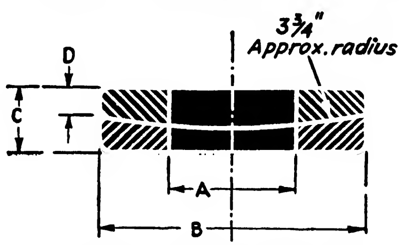
Example: $P = 400$ lb., $L = 8$, and $d = 2$. Then $P_o = 800$. From Table 2, it will be seen that a 5/8—11 NC stud will suffice for this situation.

But T is affected by the offset position of the stud and is found by taking L as twice the distance from stud to heel pin, or stud to clamping point, whichever is larger. In this case $L = 8 - 2 \times 2 = 12$ in. To find T, read up from span $L = 12$ to the curve (extended) for a 5/8-in. stud and across to left, where it is seen that $T = 1\frac{3}{4}$ in., approximately.

SPHERICAL WASHERS FOR CLAMPS

John G. Jergens, Cleveland Pneumatic Tool Company, feels that spherical washers of the type shown have a number of advantages when used under clamping nuts or knobs on jig and fixture clamps. A typical fixture, Fig. 231 shows the use of one of these spherical washer assemblies. Each of the two parts of this spherical washer assembly is made of S.A.E. 1020 steel, and is carburized, hardened, and ground after machining to shape. The sizes shown in Table 4 have been found to work best with the screw sizes indicated. Although it is not essential, it will be found advantageous to lap the mating surfaces of the two sections together for a smooth fit.

TABLE 4.—SPHERICAL WASHERS FOR JIGS AND FIXTURES



Size of screw	*A*. Diameter of hole	*B*. Outside diameter	*C*. Thickness of assembly	*D*. Thickness of washer
1/4	9/32	5/8	9/32	9/64
5/16	11/32	3/4	9/32	9/64
3/8	13/32	7/8	5/16	5/32
7/16	15/32	1	5/16	5/32
1/2	17/32	1 1/8	3/8	3/16
9/16	19/32	1 3/16	3/8	3/16
5/8	21/32	1 1/4	3/8	3/16
3/4	25/32	1 1/2	3/8	3/16
7/8	15/16	1 3/4	1/2	1/4
1	1 1/16	2	1/2	1/4
1 1/8	1 3/16	2 1/4	1/2	1/4
1 1/4	1 5/16	2 1/2	1/2	1/4
1 1/2	1 9/16	2 3/4	1/2	1/4

Section 3

ACCURACY IN DRILLED HOLES

CHAPTER VIII

DRILLING JIGS AND FIXTURES

Drill jigs probably cover a wider range of work than almost any other kind, as they vary from the small, single-hole jig which is held under the drill by hand to elaborate fixtures with many bushings to drill holes of various sizes.

In the illustrations that follow, it has been the object to show a variety of jigs and fixtures used in many kinds of work and under entirely different conditions. Some of these are extremely simple, while others are fairly complicated and used in a variety of work. With these as examples, it is believed that the tool designer can find a type of jig or fixture that will meet his requirements or will suggest a way of solving his particular problem.

Jig Drilling.—The use of drill jigs when drilling holes in duplicate parts on a production basis has come into such common use that the process needs no detailed explanation here. The rapid and accurate location of holes and the guiding of drills by means of proper jigs have effected tremendous savings in the metal-working industries.

It is, however, necessary to call attention to such factors of jig and jig-bushing design and uses as have a direct influence on the best results being obtained from drills.

Rigidity.—It is always necessary to design and construct drill jigs so that the work is securely held against movement relative to the jig and the machine table during the drilling operation. It is further necessary to have the work so supported that it does not bend as a result of the drilling pressure. This is often difficult to do, particularly if the work is thin and frail; but it should be kept in mind that bending due to this cause will result in holes that are oversize and out of line and may be responsible for much drill breakage. Thinning of drill webs and correct drill sharpening will also help to reduce drilling pressure and avoid bending of the work. Thrust and torque loads on drills are given in reference books.

Clearance for Chips.—Wherever possible, enough space should be provided between the work and the drill bushing so that chips

can be ejected by this route rather than through the bushing itself. This will materially improve the working of the drill by avoiding the clogging of chips in the flutes and by admitting more coolant to the cutting edges.

The bushing should not be placed so far away from the work, however, that the drill is allowed to bend in the space between bushing and work. If this bending is permitted, the drill will cut oversize and may break, particularly if it does not enter the work at right angles to the surface. For angular entry, it is best to have the end of the bushing placed very close to the work until the drill has fully entered and to arrange the bushing so that after the drill point is well into the work the bushing can be lifted out of the way of the chips.

Bushing Dimensions.—For proper operation of drills, the dimensions of the drill bushing are more important than its style of design. The bushing must, however, resist wear and be securely fastened in the jig. The effective length of the bushing must be sufficient to support and guide the drill. One that is too short will not keep the drill in line, because it permits the drill to bend with the short bushing acting as a fulcrum. Out-of-line and oversize holes may result.

If, on the other hand, the bushing is longer than necessary, it will cut down the useful life of the drill, or it may necessitate the use of special-length drills, thus adding to the cost of the operation. For drills having average helix angles, the length of jig bushings should be from $1\frac{3}{4}$ to $2\frac{1}{2}$ times the diameters of the drills.

The diameter of the bushing hole should be kept very close to the diameter of the drill, but under no circumstances should the bushing be so tight as to prevent the drill from turning freely. A minimum clearance of 0.0005 to 0.001 in. is desirable. It is equally important that the clearance between drill and bushing be not too great. Chipped margins on the drill often result from this cause.

Passages for Coolant.—Proper coolant, in sufficient quantities, must be supplied to the drill. It is necessary to carry away the heat generated in the cut as fast as it is produced, so that adequate passages must be provided in the jig in order that the coolant may be applied at the proper point.

When the coolant is thrown on the jig instead of on the work, its benefits are largely lost. The correct way is to have a good

stream of coolant playing on the work at the point where the drill enters. If the cross section of the work is small, much of the generated heat is radiated to its surface, and this heat can be carried away by flooding the work itself in addition to cooling the drill in the usual manner.

Drilling Angle and Blocks.—It is, of course, essential to have the drill jig as light as possible, making the designing of it (in case a hole is on an angle or out of square with other holes) very difficult in many cases. For this reason, we have what is called an angle block, such as is shown in Fig. 1.

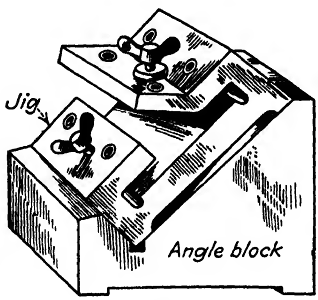


FIG. 1.

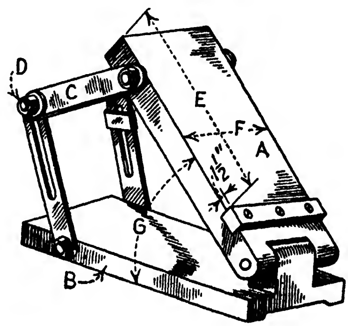


FIG. 2.

FIGS. 1–2.—Two types of angle blocks.

This is generally made of cast iron and provided with legs in the bottom, similar to the drill jig. The illustration shows a jig resting in the block.

An adjustable drilling angle is shown in Fig. 2. One or two of these drilling angles in a large factory are sufficient to take the place of a great number of angle blocks.

The plates *A* and *B* may be made of cast iron $\frac{7}{8}$ in. thick; $C = \frac{3}{8}$- by $1\frac{1}{4}$-in. cold-drawn steel; $D = \frac{1}{2}$-in. bolts. The greatest angle of *G* is about 75 deg., and the smallest 30 deg. These drilling angles should be made up in two sizes; for the large size $F = 8$ and $E = 12$ in., and for the small size $F = 6$ and $E = 10$ in.

Wedges.—The wedge is one of the simplest means known to the tool designer or -maker of holding work in the drill jig and therefore needs very little explanation. Like the cam, it has a limited amount of movement and should be used only where the variation in the size of the piece is within this amount.

Wedges are made up of square and round steel, as shown in Fig. 3. The amount of taper *a* given them varies 4 or 5 deg. to give the best results.

Figures 4 and 5 show two styles of wedges which are operated by means of a screw and held in position with gibs or screws.

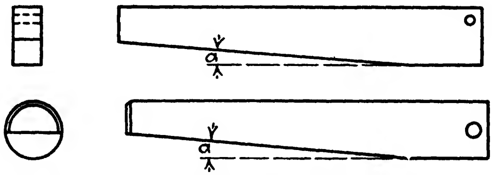


FIG. 3.—Rectangular and round wedges.

Jig for Drilling Cross Holes in Round Stock.—The base of this jig shown in Fig. 6 is a V block, and the sliding bushing plate *A* can be moved so that holes can be drilled any distance from the end of the stock within range of the device. The indi-

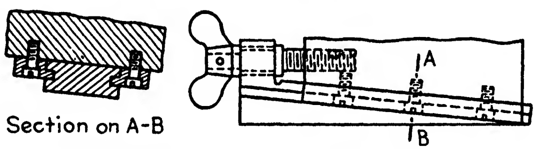


FIG. 4.—A simple screw-operated wedge.

cator and the graduations at *B* show the center distance of the bushing from the end of the work. Bushings having holes for various-sized drills are stored in holes in the base and are retained by the sliding cover plate *C*.

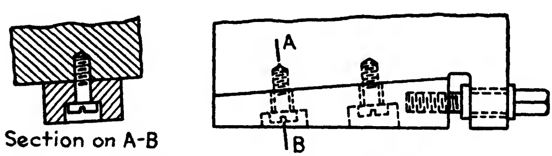


FIG. 5.—Another type of wedge.

One of the features of the jig is the auxiliary V block *D*, which is provided for holding work of small diameter close enough to the lower end of the bushing to prevent the drill from running. In the position shown, it will accommodate work from ¼ to ½ in. in diameter. By reversing its position it will accommodate work from ½ to 1¼ in. in diameter. By removing it and using the V

block in the base, work from $1\frac{1}{4}$ to $2\frac{1}{2}$ in. in diameter can be accommodated. The stop *F* for locating the work can be swung out of the way by loosening its clamping screw. The jig can be clamped to the drill-press table, the flanges *H* being provided for that purpose.

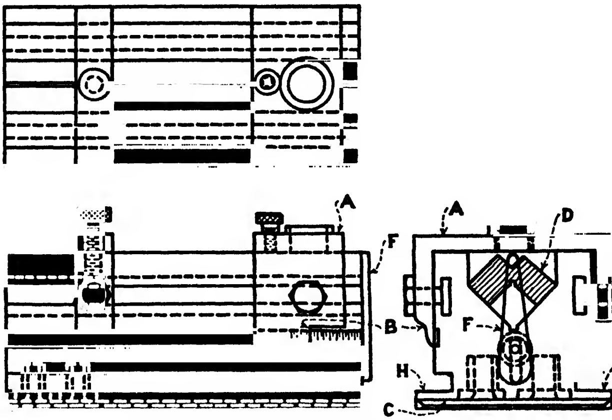


FIG. 6.—Jig for drilling round bars.

In the jig illustrated in Fig. 7, the work rests in a V block, and the distance of the hole to be drilled from the end of the work is controlled by adjustment of the stop screw *A*. The bushing plate is Z shaped, and its vertical part at the back fits in a channel in the jig body. It can be adjusted to bring the bushing close to work of

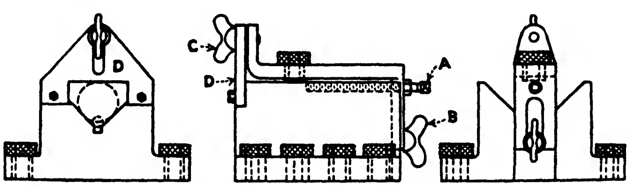


FIG. 7.—Another design for round bars.

various diameters. After adjustment to suit the diameter of the work, it is locked in position by the thumbscrews *B* and *C*. The vertical part of the bushing plate at the front is held against the plate *D*. This plate and the vertical part of the bushing plate at the back are slotted to permit adjustment.

The base of the jig is flanged at the sides, and the flanges are drilled and reamed to provide storage for extra bushings having

holes for drills of various diameters. The jig will accommodate round stock from ¼ to 1 in.

Two-position Drill Fixture.—The illustration (Fig. 8) shows a combination drill head and two-position fixture. The work is clamped in the lower part but can be moved on the lower guide bars to bring the work under either of the two bushings shown in the plate over the work holder. The drill head can also be indexed

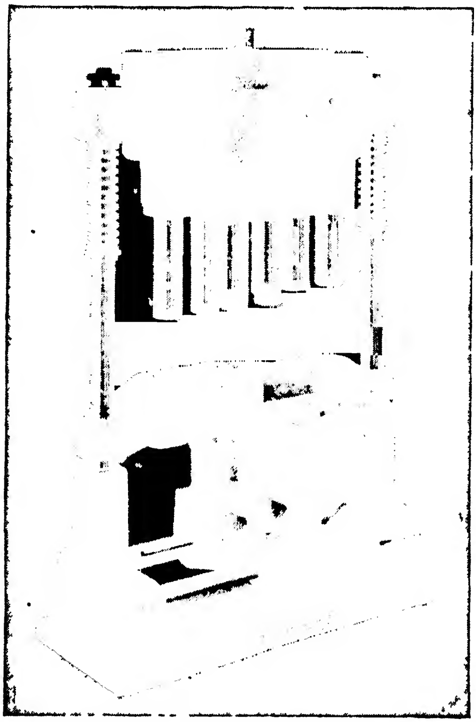


FIG. 8—Combined drill head and two-position fixture.

so as to bring its spindles in line with the bushings. In this way, the head can carry quite a variety of tools and permit several operations to be done at one setting.

Adjustable Jig for Drilling Cotter-pin Holes.—In one shop, quantities of shoulder pins and screws were to be drilled for cotter pins. Instead of making a jig for each size, the adjustable jig shown in Fig. 9 was designed.

The base was made in the form of a long V block and had a T slot at *A* running the whole length. The bushing plate *B* slid

along the base and was locked in the required position by a bolt, the head of which fitted in the T slot. Bushings of various sizes were provided, and they were threaded to screw into a tapped hole in the bushing plate and hold the work down in the V block. The base was graduated on one side, and a zero line scribed on the bushing plate, central with the tapped hole, so that the bushing could be centered at any required distance from either end. If two holes were to be drilled in one piece of work, two bushing plates were provided.

Self-adjusting Drill Jig.—A self-adjusting drill jig for balls on hand- and deck-rail stanchions or other spherical work is shown in Fig. 10. The jig was used in the marine department of the Maryland Steel Co. It was designed with the object of insuring that the holes for the rails shall be concentric with the balls and

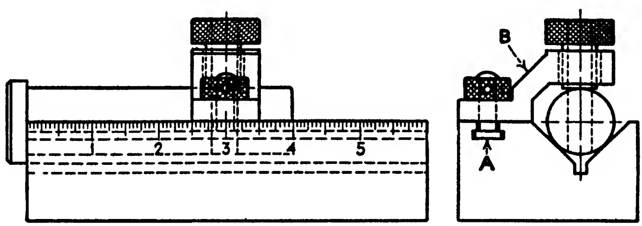


FIG. 9.—Jig for cotter-pin holes.

also practically in one vertical plane, even though it might be necessary to alter the spacing slightly on account of variations in the stanchion forgings.

It is constructed on the hinged-box principle, *A* (Fig. 10) being the upper half, which has a tapped hole to receive the drill bushing *C*. The inside is counterbored large enough in diameter to clear the ball to be drilled. *B* is the lower half, counterbored to an angle and depth large enough to seat the ball to be drilled. On the underside of *B* is a shank which projects through the slot in the base plate *D*. On the end of this shank is a square nut *E*, which acts as a gib and stop, preventing the jig body from turning too far out of position and lifting from the base plate, at the same time being free enough to allow a lateral and longitudinal movement; it is beveled to an angle of 90 deg. on the lower inside edge, to seat on the ball.

The method of operating this drill jig for a three-ball stanchion, is to unscrew the drill bushing, raise the top half of the jig body

or clamping box, insert the stanchion, close the jig, and clamp it by the tumble bolt. By this operation the drill bushing is always brought into a strictly vertical position and always in line with the drill. After clamping together the two halves of the box, the drill bushing is screwed down on the ball, centering and clamping the ball by this one operation. When the three balls are clamped by their respective bushings, there is little danger

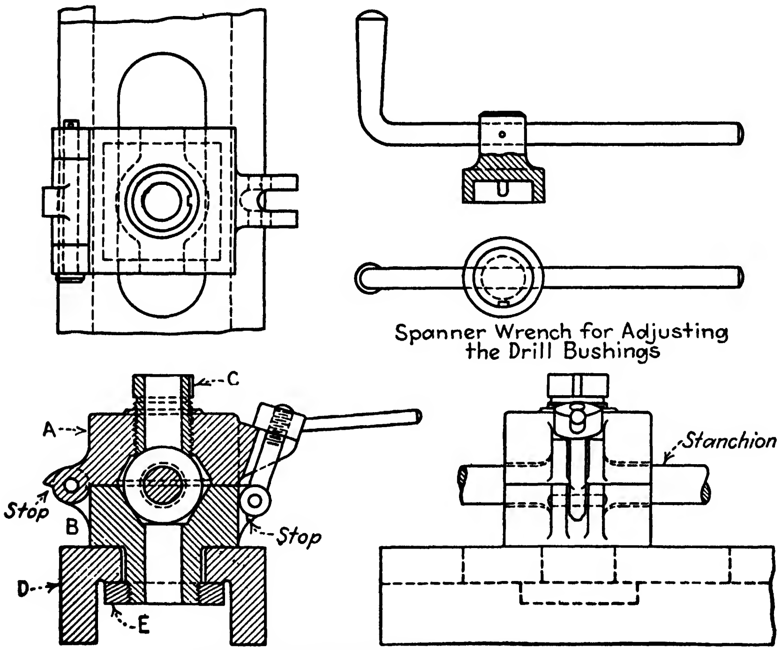


FIG. 10.—Self-adjusting jig for stanchions.

of anything's moving out of alignment, and the work leaves the jig as a first-class job.

The slots in the base plate of the present fixture allow for closing in the individual jig boxes or bodies, to drill balls at 8-in. centers; or they may spread out to 13-in. centers. The middle jig body swivels in a round hole in the center of the base plate, the adjustment for center distance being made by the two end jigs.

Combination Clamping.—The jig shown in Fig. 11 contains clamping devices of a novel character, which may be utilized in other jigs by making slight modifications in size and arrangement of parts. It is usually realized by tool designers and toolmakers

that a jig should be so designed that the various clamping screws are readily accessible to the operator's hand without his being obliged to reach behind the jig or turn the jig around or perform

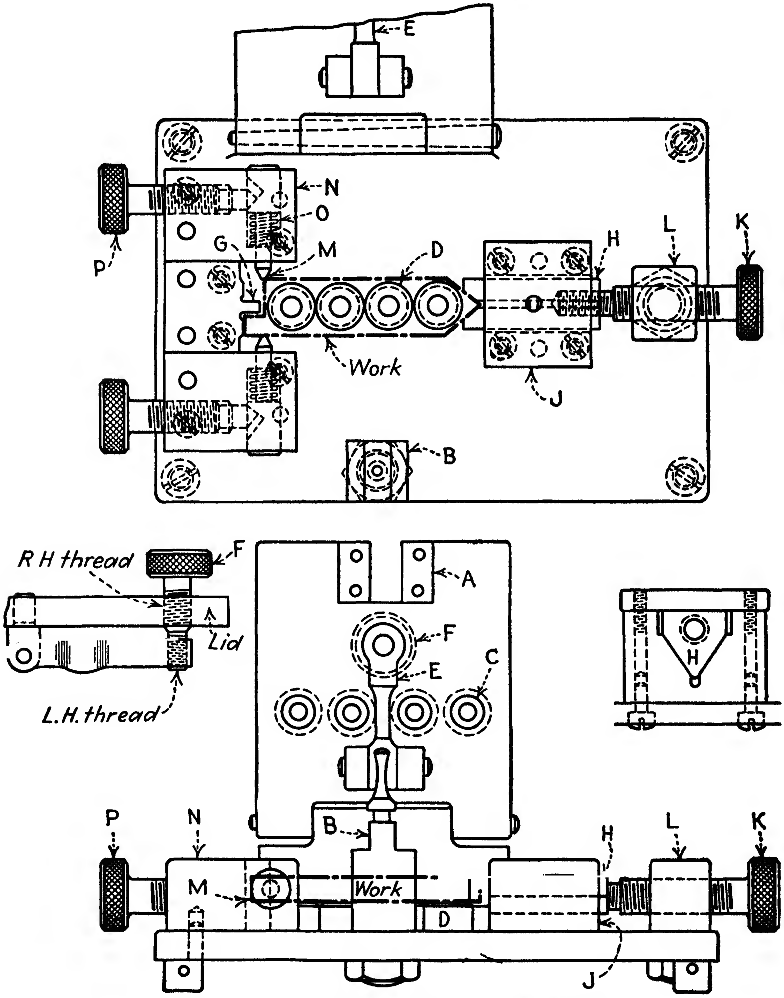


FIG. 11.—Clamping work from three points.

various other feats that are sometimes necessary with poorly or carelessly designed jigs. Every unnecessary movement of the fixture or of the operator means just so much lost in the output of the device.

In the jig under consideration, the piece being operated upon is a small steel detent plunger in which four holes are to be drilled which must bear a very accurate relation to the left-hand end cut on the plunger. These plungers are made both right- and left-handed, so that the jig must accommodate both styles.

The body and lid of the jig are made of machine steel, finished all over and left soft. The lid is hinged on a tapered pin driven into the projecting ear on the jig base, which allows the lid to turn on the pin, thus getting the largest possible bearing surface for the hinge. It is also provided with hardened-steel stop plates *A*, which take the wear caused by the blow received in closing the lid upon the locking screw post *B*. These stop plates are riveted to the lid.

The drill bushings *C* are of tool steel, hardened and ground, and are provided with large flanged heads to prevent drill-pitting the lid. The work rests upon four hardened-tool-steel posts *D*, driven into the base against a shoulder and provided with clearance holes through their centers to let the drill and the chips come through the work.

The downward clamping of the work is accomplished by means of an arm *E*, hinged to the lid at one end and depressed at the other by means of a right- and left-hand, knurled-head screw *F* (Fig. 11), which not only makes the clamp quicker acting than would be the case with a single-action screw but also does away with the necessity of providing a pivot in the end of the clamp for the screw to operate upon. The movement of this clamp is very slight, and the operating screw is a loose fit in the lid so that there is no cramping action on the clamp.

The work is held against the hardened-tool-steel locating block *G*, which is screwed to the base with two fillister-head screws from below and located with two dowel pins, which are driven into the base. The hardened-tool-steel V clamp *H*, sliding in the V way in the hardened-steel block *J* and operated by a right- and left-hand, knurled-head screw *K*, serves to force the work against the locating block *G*. The square steel post *L* in which the screw *K* operates is driven into the base against the shoulder and retained by means of a thin hexagonal nut below the base.

The location of the end of the work against the block *G* is accomplished by the pressure of sliding tool-steel plungers *M*, which operate in the tool-steel blocks *N*, and which are normally pressed

outward by springs *O* but are caused to clamp the work by the wedge action of the conical-ended knurled-head screws *P*, which operate in the blocks *N*. The upper clamp is used when drilling left-hand detents, and the lower when drilling the right-hand detents. It will be noticed that the springs and plungers are well protected from the accumulation of dirt or chips and may be readily removed for inspection or replacement by simply backing out the knurled-headed screw far enough to allow the plunger to pass the conical end of the screw.

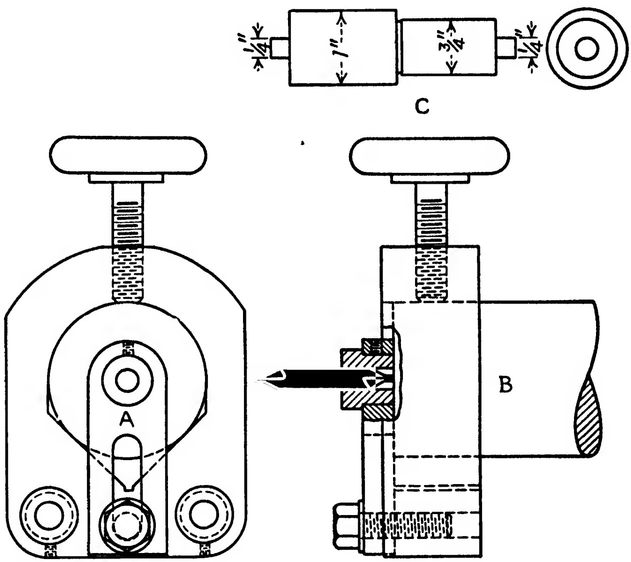


FIG. 12.—For center-drilling round stock accurately.

The jig is provided with hardened-tool-steel resting feet and also with a suitable lid stop to hold the lid in an open position just behind the perpendicular.

It will be noticed that the sliding clamp *H* retains its accuracy of alignment even after considerable wear, owing to the fact that it slides in a V way and that clearance is allowed on both sides of it above the V, as will be seen in the upper right-hand view.

Jig for Center-drilling.—The jig shown in Fig. 12 was devised by Theodore Kruger for the accurate center-drilling of round stock from 3/8 to 2 in. and square stock up to 1 1/2 in. It is intended for use in shops that do not have enough centering work to afford a regular centering machine.

The body of the jig is in the form of an enclosed V block. The bushing plate *A* is adjustable, so that the bushing can be brought over the center of work of various diameters. The view at *B* shows a center drill being guided by the bushing in the adjustable plate. At *C* is a plug turned to different diameters for convenience in setting the drill bushing. By inserting the ¼-in. end in the bushing plate and adjusting the ¾- or 1-in. diameters in the V, the plate is easily set for centering bars of these diameters. It will save time to have setting plugs for the sizes of stock generally used.

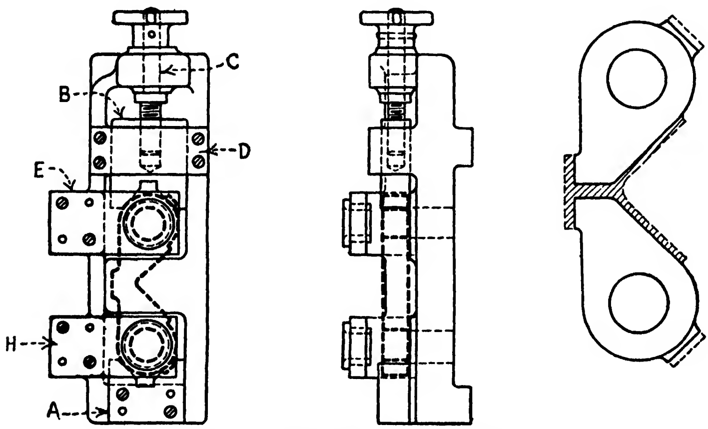


FIG. 13.—Drilling two parts at once.

Drilling Two Parts at Once.—With the object of expediting the production of ratchet pawls, an arrangement by which two pawls could be drilled together was devised and is illustrated in Fig. 13. The pawls were made of cast iron, and the machining was reduced to a minimum, as will be apparent by referring to the illustrations. The view at the right shows two pawls as they are cast together. They are ½ in. thick and are to be machined only where indicated.

Both sides of the castings are first ground in a vertical surface grinder. They are then drilled and reamed in the jig shown at the left, being held at one end by the stationary V block *A*, while the movable V block *B* is clamped against the opposite end, both V blocks being cut away to clear the small bosses. The shouldered screw *C* is operated by a hand knob and tightens the movable V block against the work. The movable V block is free to slide in

a groove in the jig base, while the plate *D* holds it down. In addition, two bushing plates *E* and *H* are attached to the top of the jig.

In use, the jig rests on the table of the drill press upon feet. The bushings are of reamer size, and a drill of the same size is used to spot the work, followed by a smaller drill. Then the holes are reamed.

Drilling and Reaming Fixture.—The fixture shown in Fig. 14 has several unusual features. It drills and reams holes accurately

FIG. 14.—Drilling and reaming fixture.

in the center plates of rayon pumps, using an indexing fixture Drilling is divided into two stages. The first set of four drills merely spots the hole locations through closely fitting bushings. The worktable is then indexed, and the spotted holes drilled without bushings. The spotted holes guide the drills for completing the work. At the next station, the four reamers finish the job.

Each work holder carries two guide pins, and there are guide bushings at each end of the upper or bushing plate. In this way, there are always four guide pins in the guide bushings, which insures correct alignment. After the worktable has been filled with work, a completely drilled and reamed plate is taken off at each operation. This fixture is from the shop of W. H. Nichols of Waltham, Mass.

Large Indexing Fixtures.—An example of a large indexing fixture from the cylinder-block line of the Ford Motor Co. is an interesting example of the extent to which this type of fixture has been developed. The fixture shown in Fig. 15 holds the cylinder block while the exhaust-valve chambers are being counterbored for the inserted valve seats. Similar fixtures are used for other cylinder operations. The block is located by dowel pins in the

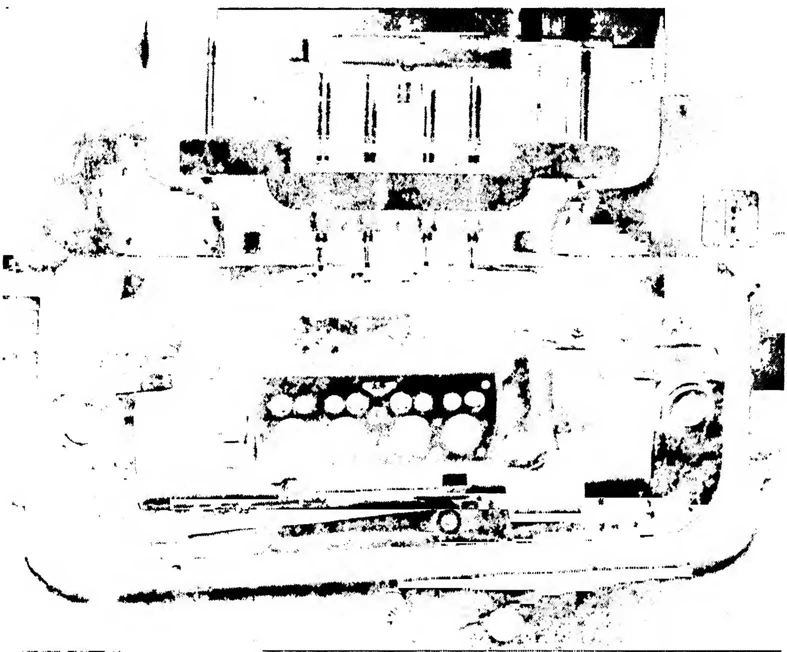


Fig. 15.—Indexing fixture for Ford V-8 cylinder block.

usual way and clamped at the ends. The way in which these clamps operate can be seen in Fig. 16. The fixture is held in its position by the heavy guide bars that enter the bushings at each end of the fixture. The boring tools are also located and guided by the heavy cross member above the block, this member being accurately positioned by the guide bars at the ends.

When these seats are bored and the tools withdrawn, the fixture is indexed to the position shown in Fig. 15, and the other four exhaust-valve seats are counterbored. The guide bars are now in the other set of guide bushings. This illustration shows the

underside of the fixture, with its heavy ribbing and the way in which the end clamps are operated. A pinion on the end of the shaft from the clamping lever operates the swinging link in the center and moves the bell crank at each end, which operates the end clamps.

These fixtures are mounted on heavy trunnions at each end. One of these trunnions has a cam which moves the whole fixture sideways as it turns, so as to bring the tools in line with the other

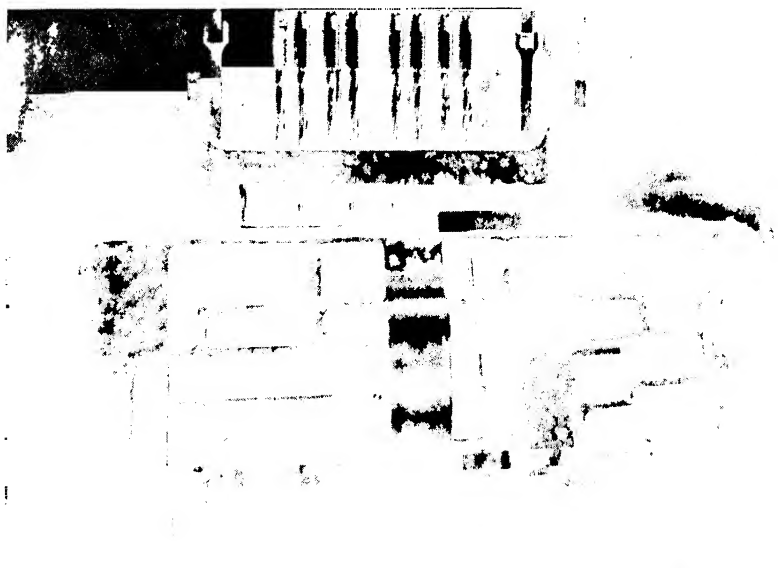


FIG 16—Underside of fixture showing operating mechanism and support.

set of valve seats, which are $\frac{7}{8}$ in. offset from the others. The indexing is done with a hydraulic cylinder.

It will also be seen that the underside of the fixture (Fig. 16) has a substantial bearing in the center to prevent sagging under its load. The bearing seats on a bored surface in the base of the cradle in which the fixture itself swings. This careful locking together of tools and fixture insures accurate work.

A Key-locked Jig.—A simple drill jig in which the work is held by a taper key is shown in Fig. 17. The jig is of steel and is hardened all over except where the jig bushings go. These spots are kept soft, and the bushing holes are finish-bored to very accurate center distances after the body is hardened. The work is

held against hardened locating pins by the key, which is so spaced as to go between the holes being drilled.

It will be noted that the four holes near the edges are drilled through the plate but that the four in the center are started only to the full diameter of the drill. This shop finds it better to locate

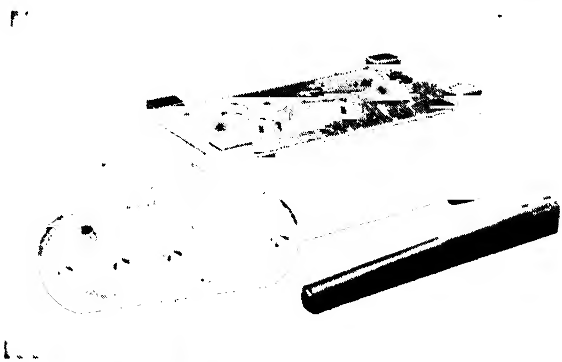


Fig. 17.—Simple jig locked with a key.

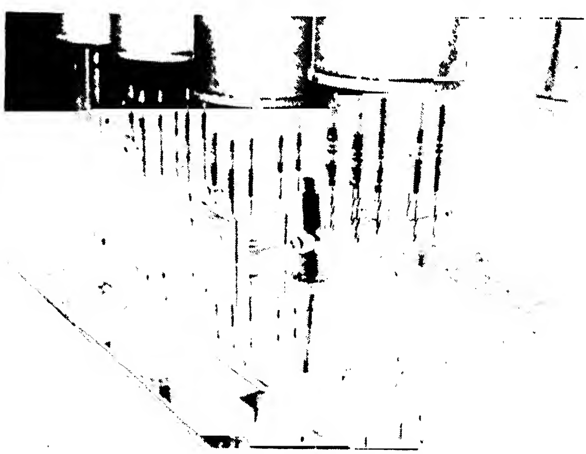


Fig. 18.—Using jig in a flooded table.

the holes by jig bushings but to finish the holes in an open jig, without bushings.

This drill jig is also used for counterboring and spot-facing by reversing it on the table, as seen in Fig. 18. This also shows how the same jig is used under four drill spindleheads and how an oil pipe, run between the drills, keeps the work flooded with lubricant during the drilling operation.

Another example of getting oil to the drill is seen in Fig. 19, where individual pipes carry the lubricant direct to the drill.

Where it is necessary to drill from several sides of a piece, the jig must be designed accordingly. A case of this kind is seen in

FIG. 19.—Piping oil to drill.

Fig. 20, which shows a typical drilling jig with feet on both sides and one edge. It has 41 holes ranging from No. 16 to No. 50 drills. The top half is removable to insert work and is located by two dowel pins in the base. The four clamping bolts are hinged

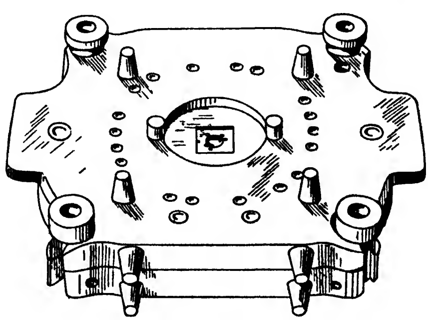


FIG. 20.—This jig drills from both sides and one edge.

at the lower end, the rounded corners of the jig permitting them to swing out of the way when loosened a half turn. The jig is of aluminum and weighs 12 lb. as against 30 lb. for cast iron The ease and speed of handling offset the added cost of the aluminum.

Guiding Bushings to Make Oilholes Match.—Insuring alignment so that the oilholes in both connecting rod and bushing will match is easily accomplished by the simple guiding plug illustrated in Fig. 21. The plug has two diameters: *A*, which is a

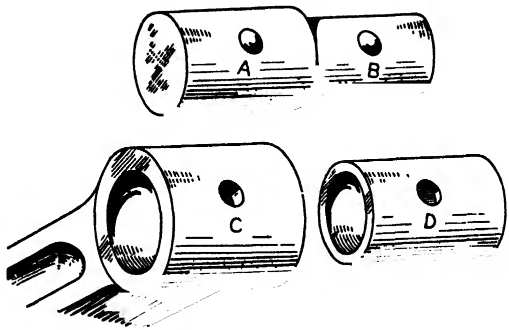


FIG. 21.—Guide bushings for assembly.

free fit in the rod end *C*; and *B*, which fits in the bushing itself. Each end of the plug carries a steel ball which projects beyond the surface and is backed by a coil spring inside the plug. These balls are in line and locate the oilholes in both bushing and rod. The bushing *D* slips over the plug at *B* and is positioned by the ball sliding into the oilhole. The large end of the plug then goes into the rod until the ball springs into the oilhole in the end. The rod with the plug and bushing is then placed under an air-operated press, and the bushing forced into the rod. The plug not only locates the oilholes but also acts as a guide to insure that the bushing gets a proper start in the hole.

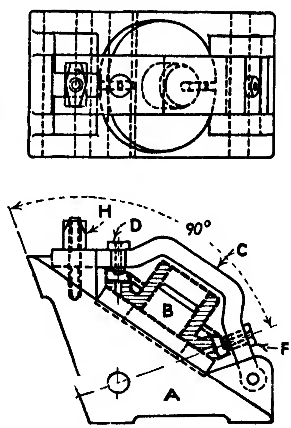


FIG. 22.—A simple roll-over jig.

A Roll-over Jig.—The jig illustrated in Fig. 22 was designed for drilling two diametrically opposite oilholes in the tooth spaces of a large quantity of bevel differential gears. Essentially, the jig consists of the base *A*, the locating plug *B*, the hinged bushing arm *C*, the bushings *D* and *F*, and the clamping nut *H*. The inner ends of the bushings are ground to fit closely between the teeth of the gear.

With the bushing arm swung up to permit loading, the gear is located by the entrance of the plug into the central hole. When the arm is brought down and is locked by the clamping nut, the gear is prevented from rotating by the inner ends of the bushings engaging the tooth spaces. The base of the jig is planed at an angle corresponding to the cutting angle of the gear, and the jig is alternately rolled over on its angular faces for drilling the holes.

Fixture for Drilling Holes at Close Quarters.—Castings, such as the one shown in heavy dotted lines in Fig. 23, requiring two ¾-in. blind holes to be drilled diametrically opposite each other from the inside of the bore, were a regular job in one shop. The

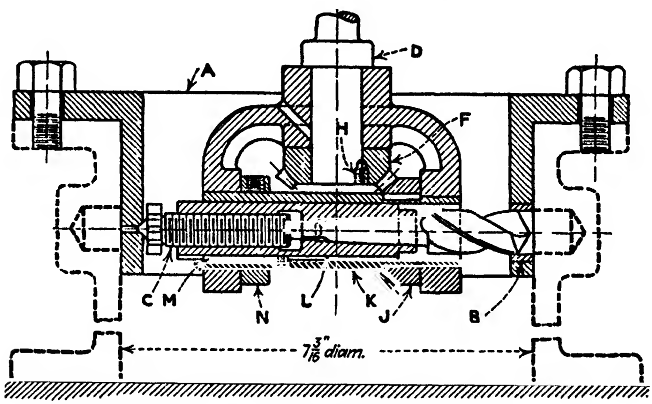


FIG. 23.—Special drill head for close quarters.

distance from the center of the holes to top of the casting was to be kept to a limit of 1/64 in. To lay out for the holes and drill them with a ratchet drill was not only too slow, but the holes could not be kept accurately within the limit required from the top of the casting, so the fixture illustrated (Fig. 23) was made.

The fixture *A* is a slip fit in the bore of the casting, being located and held by cap screws. Bushing *B* for guiding the drill is located in the fixture, and, diametrically opposite, a hole is drilled and countersunk for the conical point of the hand-operated feed screw *C*. The upper end of shank *D* fits the taper hole in the drill-press spindle, and the lower part is a running fit in the fixture. Miter gear *F* is attached to the lower end of the shank by screw *H*, and the mating gear *J* is keyed to sleeve *K*. Spindle *L* is a sliding fit in sleeve *K* and is provided with a keyway running its entire

length for the feather key M. Collar N is attached to the sleeve by a setscrew. Spindle L is drilled and reamed for the taper shank of the drill and is slotted for the tang.

Owing to the small diameter of the bore of the casting, a short drill was necessary. After one hole had been drilled, the fixture was rotated 180 deg. in the bore of the casting for drilling the opposite hole.

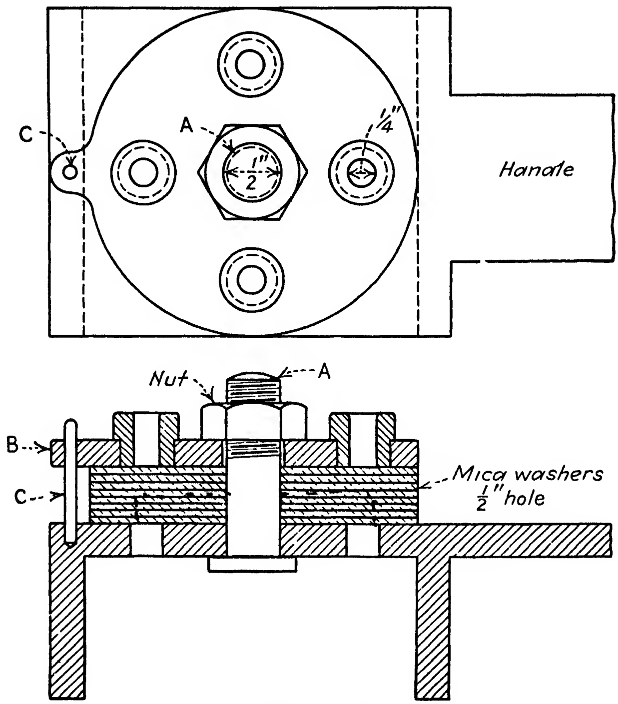


FIG. 24.—Jig for drilling mica.

Jig for Drilling Holes in Mica.—An order required a quantity of mica washers having five holes in them, as shown in Fig. 24. The outside diameter was 3 in., the center hole being ½ in., and the four edge holes ¼ in. in diameter. First, each washer was punched singly with a ½-in. hole in a power press by a standard die of this size.

These washers, piled to about ½ in. in thickness, were placed on the center pin A. A plate B, with four hardened bushings to act as drill guides, was put on the center pin and the guide C.

Then the nut was tightened, so that the washers were clamped solidly.

The washers were then drilled, as called for.

This idea can be changed to suit odd-shaped washers, by using guide pins to keep the mica pieces in line.

Such jigs save the expense of a complicated die where only a few hundred pieces are wanted at a time. It differs from other drill jigs only in the fact that the mica must be clamped tightly

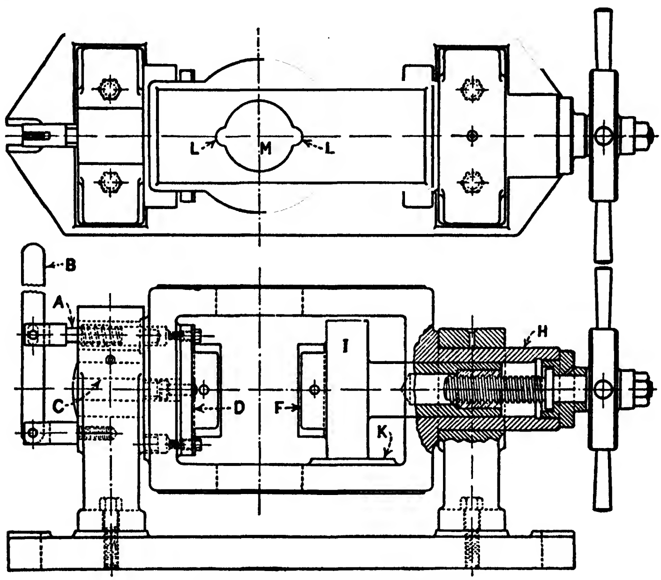


FIG. 25.—An adaptable jig.

before drilling, and no clearance is left between the drill bushing and the work.

An Adaptable Jig.—After making a separator in several sizes for a number of years, the Carrier Engineering Co. changed the design. Formerly, each size of this part was bored and faced in a turret lathe which used an individual box jig for drilling and tapping. But after the change was made, the box jigs had to be thrown away. Rather than be faced again with this situation, the company determined to make a universal jig which could be used even though the part went through further design changes; the part is produced in limited quantities, the yearly demand for each size being only about 2,000 pieces.

Therefore, they decided to design a jig that would permit operations on all sizes to be done on one machine, as otherwise several machines would be tied up. Charles C. Tomney, chief tool designer, tells how they did it.

In the indexing jig illustrated in Fig. 25, the different sizes of separators are located and held by interchangeable jaws. The jig was designed for doing all the work in a radial drill. Figure 26 shows one of the parts; operations consist in machining ends *A* and *B*, drilling and tapping 7/16-in. hole *C*, drilling 1 9/32-in.

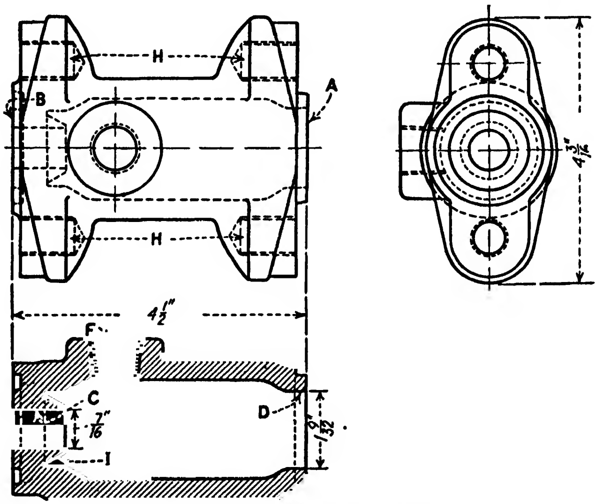


Fig. 26.—The piece to be machined.

hole *D*, drilling and tapping hole *F* for 1/2-in. pipe, and drilling and tapping four holes *H* for 5/8-in. studs. It is necessary to take only one facing cut on ends *A* and *B*, because all joints are made tight with lead gaskets.

Referring to Fig. 25, the left-hand end of the rotating part is bored and reamed to receive hardened bushings for indexing. Index pin *A* is backed by a helical spring and is operated by lever *B*. A 1-in. hole is bored true with trunnions at *C* to fit the shank of the stationary jaw holder *D*. A screw fitted with a handwheel is used to operate movable jaw *F*. Trunnion *H* is bored to receive the shank of holder *I* for the movable jaw. The bottom of this holder bears on surface *K* to prevent it from turning with the clamping screw.

Tapped holes *H* (Fig. 26) for the studs are so close to the pilots on ends *A* and *B* that it was impossible to fit bushings in the jig in the usual way for drilling them, because the facing and forming tools required such a large guide bushing. To overcome

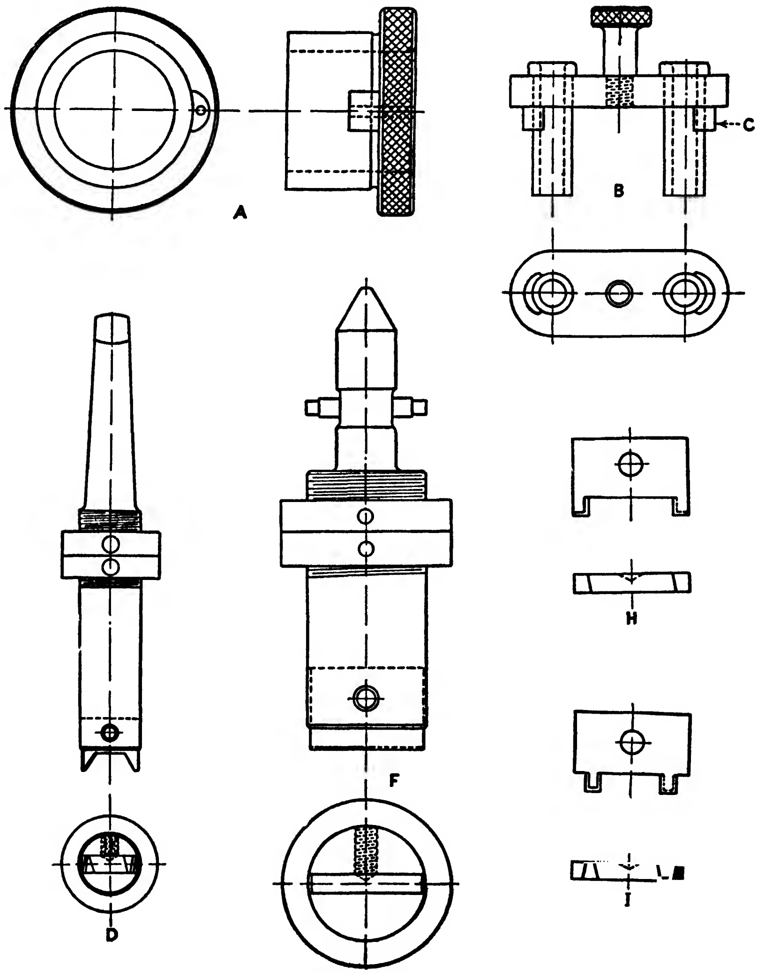


FIG. 27.—The special equipment needed for the job.

this difficulty, two holes were drilled at *L* (Fig. 25), and then hole *M* was bored for slip bushing *A* (Fig. 27), the holes *L* being cut into bushings for the tap drills were mounted in the plate *B* and are inserted in large hole *M* (Fig. 25) pins *C* engaging

the half holes *L*. This method of using an auxiliary bushing plate is one of the features of the jig.

The $1\frac{9}{32}$-in. hole *D* (Fig. 26) is drilled with a bottoming drill having the corners of the lips slightly rounded so that it will cut fairly smooth. This drill is also used to face the flat on the top of conical surface *I*, the conical part being formed by tool *D* (Fig. 27). The conical surface does not have to be accurately true because it is used only as a seat for one end of a screen

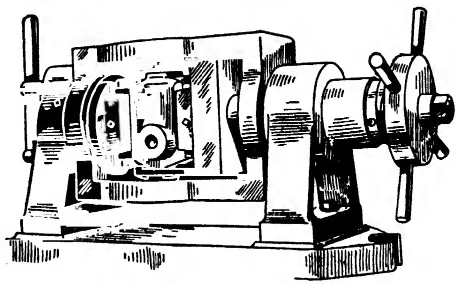


FIG. 28.—Work in place for machining and indexing.

inserted from the end *A*. The depth of cut is regulated by adjustable collars on the cutter holder, the lower one of which contacts surface *A*. Ends *A* and *B* of the work are machined by the cutters *F*, *H*, and *I* (Fig. 27). Cutters *H* and *I* are each secured in holders such as at *F*, being guided by slip bushing *A*.

The depth of cut is regulated by adjustable collars on the cutter holder, the lower one of which contacts the top of slip bushing *A*. It is not necessary to use a bushing to guide the tap drill for pipe hole *F*, since this hole is cored and the drill is allowed to follow the hole. In Fig. 28, the work is shown clamped in the jig for machining end *A*. When this end has been finished, the jig is indexed for the successive operations. Production is at the rate of four per hour, floor to floor.

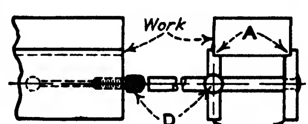


FIG. 29.—Parallels for use in drilling.

Parallels for Drilling.—In drilling steel, a considerable burr is formed where the drill comes through, and the duller the drill the bigger and heavier is the burr. Unless the work is placed on parallels, the burr will have to be removed before drilling other holes, or the work will not lie flat.

In the illustration (Fig. 29) are shown improved parallels for mounting work for drilling and reaming. They may be made of tool steel and hardened or of machine steel and pack hardened. The steps *A* should be about 1/8 in. deep and 3/16 in. wide. A piece of drill rod is riveted in a hole in parallel *B* and slides in a clearance hole in parallel *C*. Thus the parallels are adjustable for distance apart for holding work of different widths, and they can be locked in adjustment by the knurled-head screw *D*, which bears on one end of a brass rod fitting loosely in a hole drilled lengthwise in parallel *C* and into the transverse hole for the drill rod. The opposite end of the brass rod is in contact with the drill rod and is pinched against it by turning the knurled-head screw.

In use, the parallels are spread apart sufficiently to admit the work to the steps *A* and are then locked by the knurled-head screw. Any number of holes can now be drilled and reamed in the work, and the burrs will not have to be removed until after all the drilling and remaing have been completed.

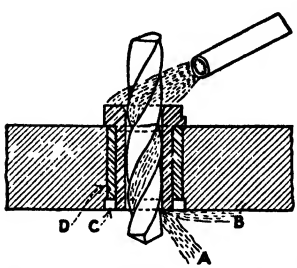


Fig. 30.—Keeping a drill cooler by a recess at bottom.

Keeping a Drill Cooler.—The method indicated in Fig. 30 has been used to supply additional flooding of the drill by the coolant or lubricant. The rotary motion of the drill imparts centrifugal force to the coolant as it is ejected from the bottom of the bushing, as at *A*. Through capillary attraction, the coolant has a tendency to run along the underside of the bushing plate, as at *B*. This action may be seen as one or more steady streams which continuously flow along the under surface of the bushing plate.

By counterboring a recess 1/8 in. deep and wide at the bottom of the bushing plate, as at *C*, the capillary action is broken, resulting in an increased cooling and lubricating of the drill. Where a liner bushing is used, as at *D*, it should be 1/8 in. shorter than the drill bushing, leaving a recess. Otherwise, the recess must be made by counterboring. It is desirable to limit the distance between the drill and the recess to not more than 3/16 in. to prevent side drainage, since a wider surface at this point helps to build up a strong flow of coolant under the bushing plate.

The use of this method has effected a 10 per cent saving in drills used on drop forgings in drilling holes of a depth of about three diameters.

Universal Jigs.—Jigs that can be adapted to a variety of uses have been developed by several concerns, who manufacture the parts in quantities and combine them in a variety of ways. These consist of a base and a top plate which is supported by plungers which fit into suitable bearings in the base itself. The top plate carries the drill bushings and also clamps the work on the base. It is operated either by rack and pinion, the rack being cut in the plunger itself, or by a cam of one sort or another.

Such jigs are frequently called "universal," although this is, perhaps, a rather inclusive term for them. They are very convenient for many kinds of work and permit rapid handling of it. They are also adaptable to a large variety of pieces, the same base being frequently used with a number of different top plates.

Some of the concerns making jigs of this kind have standardized the different parts, such as locking devices, levers, crank handles, racks, bases, and top plates. With a list of these parts before him, the designer can frequently save money by purchasing such parts instead of attempting to make them in the ordinary tool-room. Just as few shops would now consider making their own drill bushings, unless a special size was necessary, so it is likely that time and money can be saved by using other standard parts that may be available.

Fixtures for Radial-drill Work.—Radial-drilling machines are particularly adaptable for work of medium and fairly large sizes, especially where holes of various sizes must be drilled and where the quantity does not warrant the use of large, way-drilling machines. With the quick-change drill holders now so commonly used, work of this kind can be handled rapidly and economically. An example of this kind is seen in Fig. 31, where the fixture has drill bushings on more than one side. The different holes are readily reached by moving the drill head. The bench behind the drill holds the various drills used and their holders in a convenient position for the operator.

A more complex radial-drill fixture is shown in Fig. 32. Here a pit has been dug beside the drill table. On the table is a trunnion support on which the plate carrying the work can be turned to bring various surfaces under the drill. It is also interesting

FIG. 31.—Drilling fixture for a radial machine.

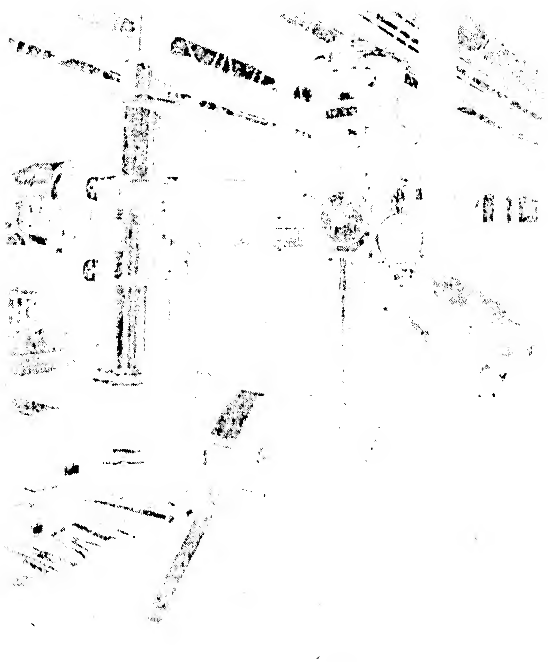


FIG. 32.—Special fixture for use with radial drill.

to note that the drill bushings being used are mounted in the ends of flat steel plates which fit into the jaws of the bearing. With the bushing plate clamped in position, as shown, the holes for the bearing-cap studs can be readily drilled.

On the other side of the drill column is another piece of work, supported by suitable blocking. Portable bushing plates are clamped on the piece of work, and holes drilled in different side

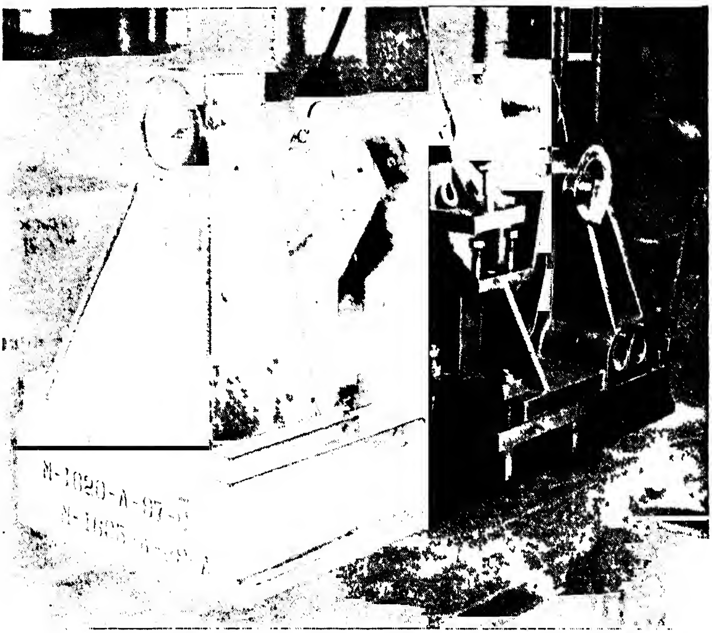


FIG 33.—Boring fixture for gear-box housing.

positions. In this way, one man can be setting up the work on one side while the work is being drilled on the other. Thus, the drilling machine can be kept busy most of the time, which is the way to get the most out of the investment in expensive machinery.

In some shops, a large circular table has been put around a radial drill so that work can be set up anywhere on the table while the operator is drilling the first piece of work. This also saves a lot of time for the machine.

Unusual Boring Fixture.—The boring fixture shown in Fig. 33 is unusual in several ways. It is for the gear box of a well-

known precision machine in which three holes must be bored with a fixed relation to each other and within very close limits. The center support for the boring bar is removable and is put in place after the casting has been put in position in the fixture. This loose center piece is located by the handled dowel pin, or gudgeon, shown at the end, over the two bolts that hold the center piece in place. The holes in the end of the crosspiece are large enough for the nuts to pass through, the C washers holding the piece in place. Correct location is secured by the dowel previously mentioned.

With the piece of work in place, the fixture guides three boring bars in each direction, as can be seen by a little study. The different methods of clamping the work are also worthy of study. This fixture is being successfully used on one of the most accurate machine tools built.

CHAPTER IX

DRILL-JIG BUSHINGS

After several attempts, extending over a period of years, to make drill bushings as a special appliance for the trade, they have now become established as a part of jig and fixture work, and few concerns make their own drill bushings if they can be purchased from a manufacturer who specializes in them. Standard dimensions have now been adopted by bushing manufacturers and users, and these dimensions together with the standard definitions of parts and kinds are given later to prevent confusion. These standards have been adopted by committees of the American Society of Mechanical Engineers and the Society of Automotive Engineers and have been approved by American Standards Association. They will be given in this chapter. Practically speaking, only special bushings are now made by the makers of jigs and fixtures.

Fixed bushings, or sleeves, are common in many types of jigs, being pressed in with a light pressure to prevent movement. Where slip bushings are used, as in cases where it is necessary to change sizes, such as for tap drills and body drills, it is now customary to press a permanent bushing, or liner, into the jig to receive the slip bushing. This helps in maintaining accuracy of hole location, as the hardened permanent bushings do not wear as do the castings of which fixtures are usually made.

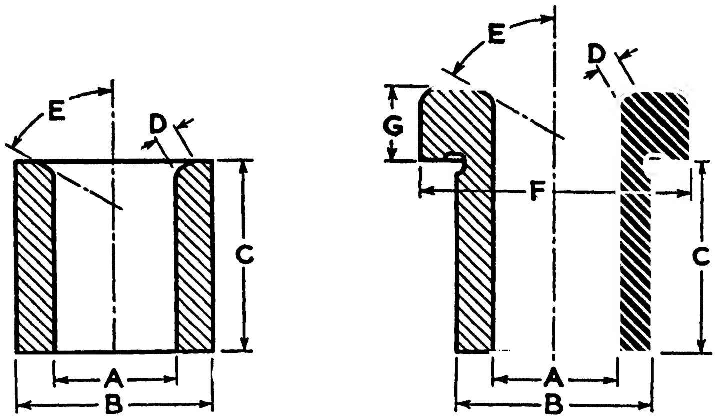
Screw bushings are sometimes used to hold the piece in the jig as well as to guide the drill. These have largely been abandoned by jig designers because of the difficulty of maintaining accuracy in the screw bushing. Any eccentricity between the thread and the hole in the bushing changes the location of the hole drilled with every position of the bushing in the threaded hole. Where threaded or screw bushings must be used, concentricity can best be maintained by first finishing the hole and mounting the bushing on a true mandrel on which the thread should be ground to size. Many designers avoid the screw bushing wherever possible. Some make the thread a loose fit and guide the bushing by a ground, cylindrical portion.

STANDARD JIG BUSHINGS

Nomenclature and Introductory Notes

Press-fit Bushings.—Press-fit wearing bushings to guide the tool are for installation directly in the jig without the use of a

TABLE 1.—PRESS-FIT WEARING BUSHINGS, HEADLESS AND HEAD TYPES



Range of hole size[1,2] A		Body diameter B					Body length[4] C			Width of chamfer[5] D	Head diameter[6] F Max.	Head height G Max.
		Unfinished[3]			Finished							
From	Up to and including	Nominal	Max.	Min.	Max.	Min.	Short	Medium	Long			
0.0156	0.0625	5/32	0.166	0.161	0.1578	0.1575	5/16	...	1/2	1/32	1/4	3/32
0.0630	0.0995	13/64	0.213	0.208	0.2046	0.2043	5/16	...	1/2	1/32	5/16	3/32
0.1024	0.1378	1/4	0.260	0.255	0.2516	0.2513	5/16	...	1/2	1/32	3/8	3/32
0.1406	0.1875	5/16	0.327	0.322	0.3141	0.3138	5/16	1/2	3/4	1/32	7/16	1/8
0.1910	0.2500	13/32	0.421	0.416	0.4078	0.4075	5/16	1/2	3/4	1/16	17/32	5/32
0.2520	0.3125	1/2	0.520	0.515	0.5017	0.5014	5/16	1/2	3/4	5/64	5/8	7/32
0.3160	0.4219	5/8	0.645	0.640	0.6267	0.6264	1/2	3/4	1	3/32	13/16	7/32
0.4375	0.5000	3/4	0.770	0.765	0.7518	0.7515	1/2	3/4	1	7/64	15/16	7/32
0.5156	0.6250	7/8	0.895	0.890	0.8768	0.8765	3/4	1	1 3/8	7/64	1 1/8	1/4
0.6406	0.7500	1	1.020	1.015	1.0018	1.0015	3/4	1	1 3/8	7/64	1 1/4	5/16
0.7656	1.0000	1 3/8	1.395	1.390	1.3772	1.3768	3/4	1	1 3/8	9/64	1 5/8	3/8
1.0156	1.3750	1 3/4	1.770	1.765	1.7523	1.7519	1	1 3/8	1 3/4	9/64	2	3/8
1.3906	1.7500	2 1/4	2.270	2.265	2.2525	2.2521	1	1 3/8	1 3/4	7/32	2 1/2	3/8

All dimensions given in inches.

Tolerance on fractional dimensions where not otherwise specified shall be ±0.010 inch.

[1] Hole sizes are in accordance with the American Standard for Twist Drill Sizes (ASA (B5.12–1940). [2] The maximum and minimum values of the hole size *A* shall be as follows:

Nominal Size of Hole	Maximum	Minimum
Above 0.0000 to 1/4 in. incl.	Nominal +0.0004 in.	Nominal +0.0001 in.
Above 1/4 to 3/4 in. incl.	Nominal +0.0005 in.	Nominal +0.0001 in.
Above 3/4 to 1 1/2 in. incl.	Nominal +0.0006 in.	Nominal +0.0002 in.
Above 1 1/2	Nominal +0.0007 in.	Nominal +0.0003 in.

[3] The body diameter *B* for unfinished bushings is larger than the nominal diameter in order to provide grinding stock for fitting to jig plate holes. The grinding allowance is
0.005 to 0.010 in. for sizes 5/32, 13/64, and 1/4 in.,
0.010 to 0.015 in. for sizes 5/16 and 13/32 in., and
0.015 to 0.020 in. for sizes 1/2 in. and up.

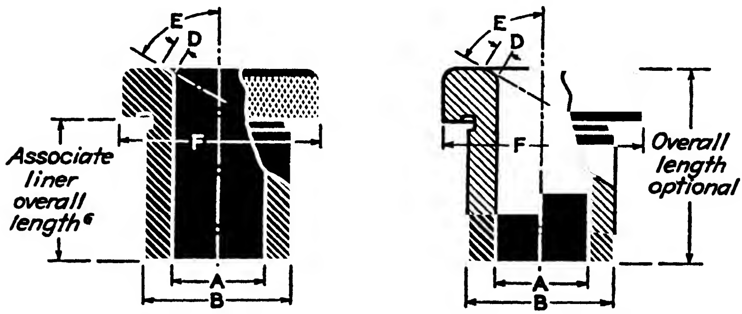
[4] The length *C* is the overall length for the headless type and the length underhead for the head type.

[5] The angle of chamfer *E* shall be 59 deg ±1 deg and a slight radius shall be provided at the intersection of this chamfer with the hole *A*.

[6] The head design shall be in accordance with the manufacturer's practice.

liner and are employed principally where the bushings are used for short-production runs and will not require replacement. They are intended also for use where the closeness of the center distance of holes will not permit the installation of liners and renewable bushings. Press-fit bushings are made in two types,

Table 2.—Renewable Wearing Bushings, Slip and Fixed-head Types



Range of hole size[1,2] *A*		Body diameter *B*			Width of chamfer[3] *D*	Head diameter[4] *F* Max.
From	Up to and including	Nominal	Max.	Min.		
0.0000	0.1562	5/16	0.3125	0.3123	1/32	5/8
0.1610	0.3125	1/2	0.5000	0.4998	5/64	15/16
0.3160	0.5000	3/4	0.7500	0.7498	7/64	1 1/4
0.5156	0.7500	1	1.0000	0.9998	7/64	1 5/8
0.7656	1.0000	1 3/8	1.3750	1.3747	9/64	2
1.0156	1.3750	1 3/4	1.7500	1.7497	9/64	2 1/2
1.3906	1.7500	2 1/4	2.2500	2.2496	7/32	3

All dimensions given in inches.

Tolerance on fractional dimensions where not otherwise specified shall be ±0.010 inch.

[1] Hole sizes are in accordance with the American Standard for Twist Drill Sizes (ASA B5.12–1940).

[2] The maximum and minimum values of hole size *A* shall be as follows:

Nominal Size of Hole	Maximum	Minimum
Above 0.0000 to 1/4 in. incl.	Nominal +0.0004 in.	Nominal +0.0001 in.
Above 1/4 to 3/4 in. incl.	Nominal +0.0005 in.	Nominal +0.0001 in.
Above 3/4 to 1 1/2 in. incl.	Nominal +0.0006 in.	Nominal +0.0002 in.
Above 1 1/2	Nominal +0.0007 in.	Nominal +0.0003 in.

[3] The angle of chamfer *E* shall be 59 deg ±1 deg and a slight radius shall be provided at the intersection of this chamfer with the hole *A*.

[4] The head design shall be in accordance with the manufacturer's practice.

[5] Head of slip type is usually knurled.

[6] When renewable wearing bushings are used with liner bushings of the head type, the length under head should be increased over the jig plate thickness by the thickness of the liner bushing head.

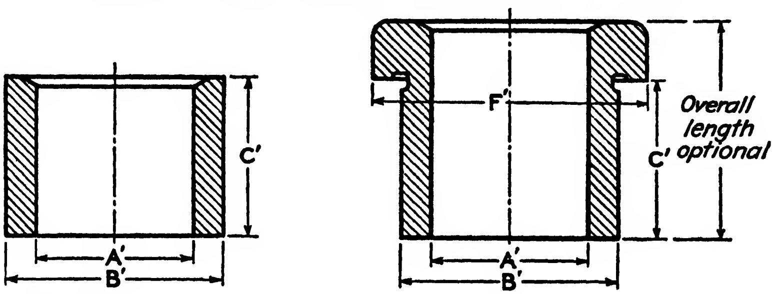
with heads and without, as shown, in Table 1. All dimensions in tables are in inches.

Renewable Bushings.—Renewable wearing bushings to guide the tool are for use in liners which in turn are installed in the jig. They are used where the bushing will wear out or become obsolete before the jig or where several bushings are to be interchangeable in one hole. Renewable wearing bushings are divided into two classes, "fixed" and "slip."

Fixed renewable bushings are installed in the liner with the intention of leaving them in place until they are worn out.

Slip renewable bushings are interchangeable in a given size of liner, and, to facilitate removal, they are usually made with a

TABLE 3.—LINER BUSHINGS, HEADLESS AND HEAD TYPE



Range of hole size of renewable wearing bushings[1]		Inside diameter A'			Body diameter B'					Jig plate thickness[3] C'			Head diameter[4] F' Max.
					Unfinished[2]			Finished					
From	Up to and including	Nominal	Max.	Min.	Nominal	Max.	Min.	Max.	Min.	Short	Medium	Long	
0.0000	0.1562	5/16	0.3129	0.3126	1/2	0.520	0.515	0.5017	0.5014	5/16	1/2	3/4	5/8
0.1610	0.3125	1/2	0.5005	0.5002	3/4	0.770	0.765	0.7518	0.7515	5/16	1/2	3/4	5/16
0.3160	0.5000	3/4	0.7506	0.7503	1	1.020	1.015	1.0018	1.0015	1/2	3/4	1	1 1/4
0.5156	0.7500	1	1.0007	1.0004	1 3/8	1.395	1.390	1.3772	1.3768	3/4	1	1 3/8	1 5/8
0.7656	1.0000	1 3/8	1.3760	1.3756	1 3/4	1.770	1.765	1.7523	1.7519	3/4	1	1 3/8	2
1.0156	1.3750	1 3/4	1.7512	1.7508	2 1/4	2.270	2.265	2.2525	2.2521	1	1 3/8	1 3/4	2 1/2
1.3906	1.7500	2 1/4	2.2515	2.2510	2 3/4	2.770	2.765	2.7526	2.7522	1	1 3/8	1 3/4	3

All dimensions given in inches.

Tolerance on fractional dimensions where not otherwise specified shall be ±0.010 inch.

[1] For detail dimensions of renewable wearing bushings see Table 2.

[2] The body diameter B' for unfinished bushings is 0.015 to 0.020 in. larger than the nominal diameter in order to provide grinding stock for fitting to jig plate holes.

[3] The length C' is the overall length for the headless type and the length under head for the head type.

[4] The head design shall be in accordance with the manufacturer's practice.

Overall length is optional.

knurled head. They are most frequently used where two or more operations requiring different inside diameters are performed in a single jig, such as where drilling is followed by reaming, tapping, spot facing, counterboring, or some other secondary operation (see Table 2). Heads are machined for locking mechanism.

Liner Bushings.—Liner bushings are provided with and without heads and are permanently installed in a jig to receive the renewable wearing bushings. They are sometimes called "master bushings" and are shown in Table 3.

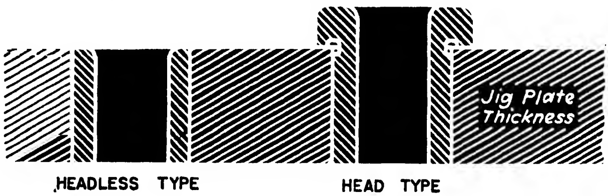


FIG. 34.—Press fit bushings.

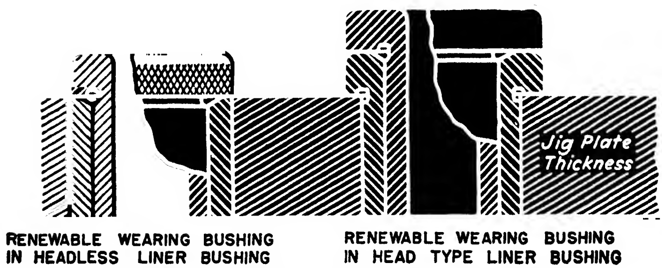


FIG. 35.—Liner bushings—headless and head type.

Bushing Specifications.—The dimensions and tolerances of jig bushings shall conform to the specifications given in the preceding tables and notes.

Jig-plate Thickness.—The standard lengths of jig bushings as established are based on standardized or uniform jig-plate thicknesses of 5/16, 1/2, 3/4, 1, 1 3/8, and 1 3/4 in.

The method of using these bushings is shown in Figs. 34 and 35.

SPECIAL BUSHINGS

In addition to the standard bushings shown, there are times when it is advisable or convenient to use special bushings. The accompanying illustrations show a large number of these which experience has shown to be useful on occasion. It is advisable.

however, to use standard bushings wherever possible. The illustrations also show the proportions that have proved satisfactory. Generally speaking, the length of a bushing should be approximately twice the diameter. It should project from 1/16 in. for small bushings to 1/4 in. for the larger sizes.

Stationary bushings are chamfered slightly on the end to prevent shearing or shaving the hole as they are forced into place. The entering end is sometimes ground to a sliding fit in the bushing hole for a short distance or ground at a slight taper. The body of the bushing is ground straight with an allowance of 0.002 to 0.003 in. for the press fit. In some cases, for thin-walled holes, this fit allowance is cut in half.

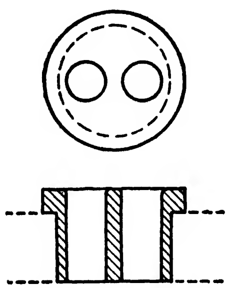


FIG. 36.—Two holes in one bushing.

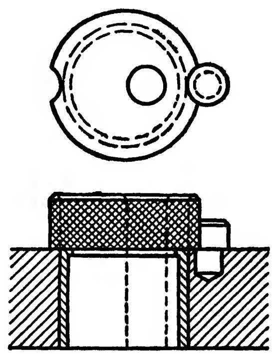


FIG. 37.—Eccentric bushing for drilling two holes close together.

In making slip bushings, it is advisable to have the head appreciably larger than the liner, or fixed, bushing. In this way, the head of the slip bushing will strike the body of the jig and prevent the liner's being forced down by undue pressure, as the stop collar strikes the bushing.

Bushings for Two Holes.—It often happens that two or more holes are so close together that it is impossible to have independent bushings for each hole, and these are then placed in one bushing, as shown in Fig. 36, or one hole is put in an eccentric bushing, as shown in Fig. 37. This bushing is then reversed for drilling the second hole.

Bracket Bushings.—It is also found in many cases that a round bushing cannot be used at all, and in such instance it is good practice to make the bushing in the form of a bracket, as

shown in Fig. 38. The hole *A* guides the drill or reamer, and the body *B* is screwed on the wall of the jig and dowel pinned when in place.

Removing Slip Bushings.—It is always necessary to provide means for removing slip bushings. The illustrations show a few schemes that work out well, Figs. 39 to 42 being generally used. This method permits the use of a screw driver for removing the bushings and applies only to small sizes.

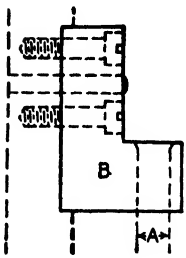


FIG. 38.—Bracket bushing for close quarters.

For the larger sizes, handles can be attached to the head of the bushing as shown. In some designs, a pin *B* can be placed in the jig, as shown in Fig. 43, or a handle *A* can be bent, as shown in Fig. 44, to prevent the bushing from turning. Figures 45 and 46 show two other kinds of handle.

To Prevent Bushings from Turning.—Another important feature which is too often overlooked is means for preventing bushings (especially small sizes) from turning or coming out. A few of the methods used are shown. Figures 47 and 48 permit the

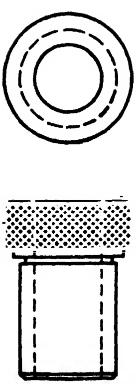


FIG. 39.

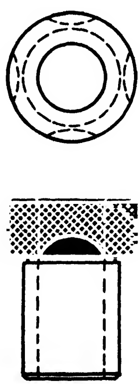


FIG. 40.

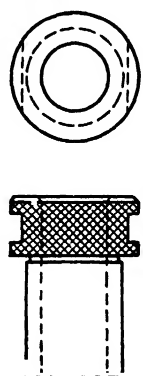


FIG. 41.

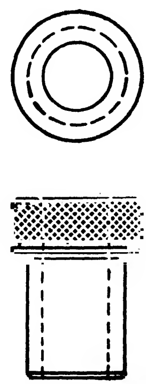


FIG. 42.

FIGS. 39–42.—Four types of bushing heads.

bushing to turn but hold it in place, while Figs. 49 and 50 hold it in place and also prevent the bushing from turning. Figure 51 is also used. The pin turns, so that the head can engage the slot.

Screw Bushings.—Figure 52 is a standard screw bushing which is used as a guide for a drill and also acts as a means to hold or

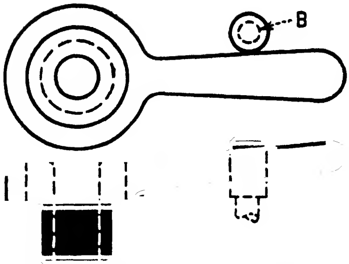


FIG. 43.—Stop pin for handle.

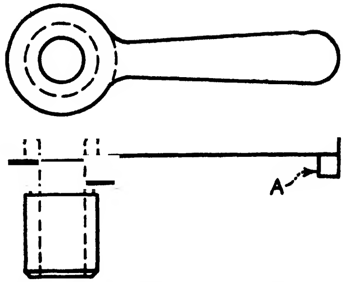


FIG. 44.—Handle bent down to contact a stop.

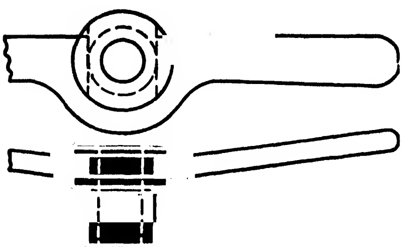


FIG. 45.—Double handle slipped into a groove in bushing.

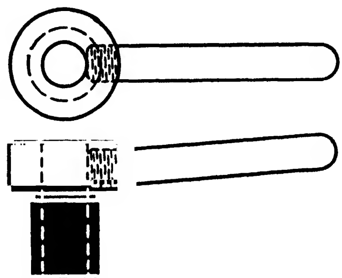


FIG. 46.—Handle screwed into bushing.

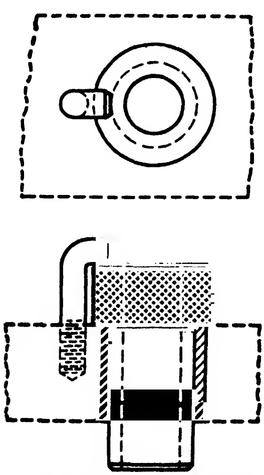


FIG 47.—The hook prevents the bushing from coming out.

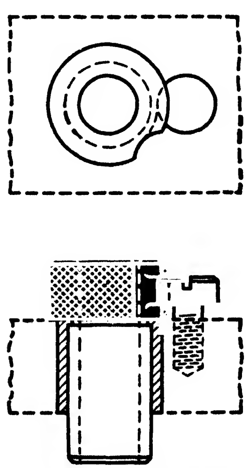


FIG. 48.—A screw fitting into a groove holds this bushing.

help hold the work while being drilled, or it may also act as a guide by being cupped, as shown in Fig. 53. As before stated, these are not recommended for accurate work.

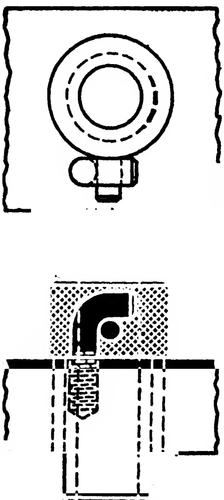


FIG. 49.—This hook prevents bushing from turning.

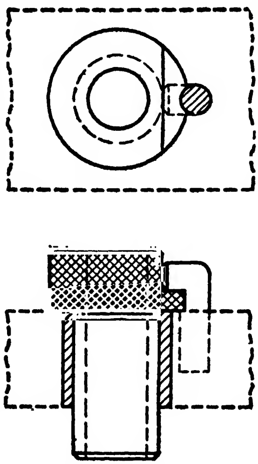


FIG. 50.—Another kind of hook.

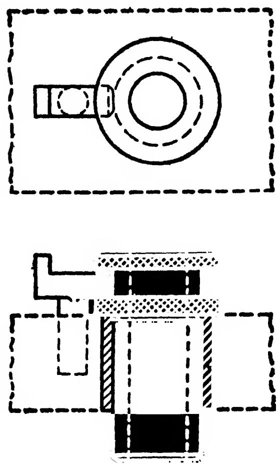


FIG. 51.—This pin turns to engage the slot.

The illustrations shown in Figs. 54 and 55 are common forms of screw bushing containing a slip bushing. Figure 54 shows the general practice when designing or making a bushing that

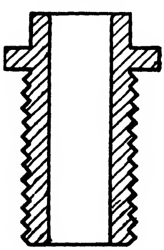


FIG. 52.—Plain screw bushing.

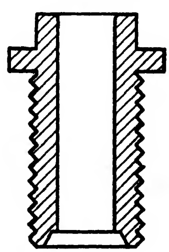


FIG. 53.—End cupped to guide or center work.

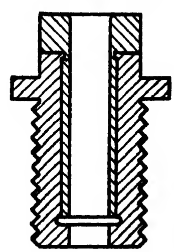


FIG. 54.—Screw bushing with a slip sleeve or bushing inside.

is to act simply as a means for holding the work, and Fig. 55 when it is desired to hold and also guide the work by means of the cupped end.

Accurate Screw Bushings.—If extreme accuracy is desired, the bushings should be constructed as shown in Fig. 56. This is the style more commonly used. In either case, the thread should be an easy fit to allow the pilot of bushing *A* to have a sliding fit, as this should act as the guide rather than the thread. In this construction, it is well to have a hardened and ground

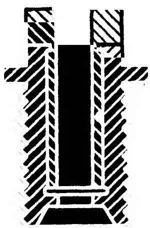


FIG. 55.—Similar bushing with a cupped end.

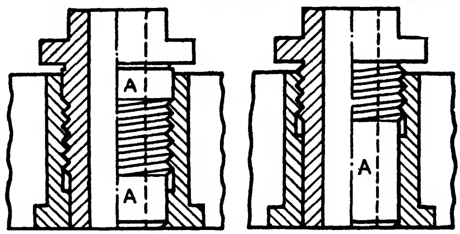


FIG. 56.—Two designs where the bushing is not guided by the thread but by plain surfaces.

stationary bushing for them to work in, so that in case of wear they can be removed. This is good practice for all styles of screw bushings.

For operating the screw bushings, it is customary to use a monkey or screw wrench, although special wrenches can be made up as shown. These are used in conjunction with the screw bush-

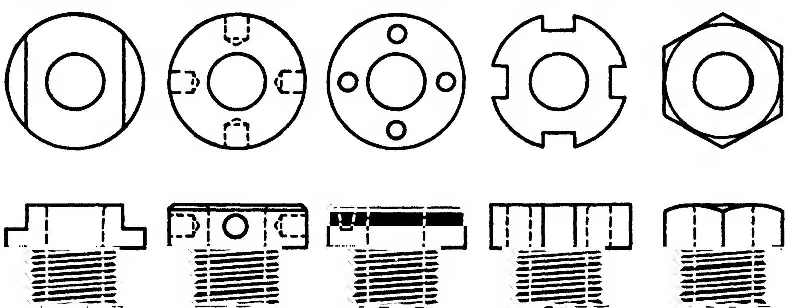


FIG. 57. FIG. 58. FIG. 59. FIG. 60. FIG. 61.

FIGS. 57–61.—Different forms of heads for screw bushings.

ings shown. Figures 57 and 58 give the style head most commonly seen. Figures 59 to 61 show other forms of heads on screw bushings.

Bushings are made of low-carbon steel, carbonized by any good method, hardened, and ground. They are also made of high-carbon, or tool, steel and heat-treated in the usual manner.

CHAPTER X

TYPES OF DRILL JIGS AND FIXTURES

With so many types of jigs and fixtures, representing not only a wide variety of work but also the ideas of many different designers, it is difficult to select names that will be understood in all parts of the country. In order to give an idea as to the

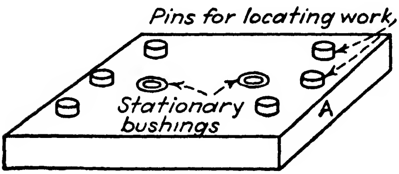


FIG. 62.

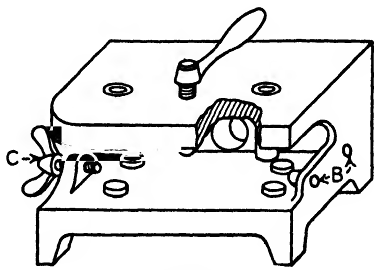


FIG. 63.

FIG. 62.—Plate or temporary jig.

FIG. 63.—Open-front or open-face jig. The part is held against hardened locating points *B* by screw *C*. The hole at back is for pushing work out if necessary.

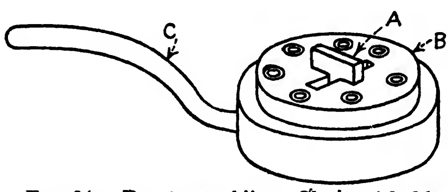


FIG. 64.—Pan type of jig. Clamp *A* holds bushing plate *B*. Handle *C* is for convenience in moving, and for holding jig while fastening the work.

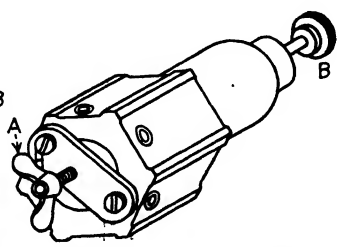


FIG. 65.—A "hex" type of jig. Work held by screw *A* in swinging latch. Plunger *B* forces work out. Designed for drilling pin wrench holes in a collar.

construction and uses of a number of different types, they have been selected and grouped, together with an explanatory caption, in the belief that this will be more convenient than being obliged to refer to the text in each case. While many of these fixtures

were designed for a special purpose and may not be applicable to a large variety of work, there are but few instances where an ingenious designer cannot find a suggestion or idea that can be applied in other cases. In fact, it is generally true that designs and ideas must be *adapted* rather than *adopted* bodily.

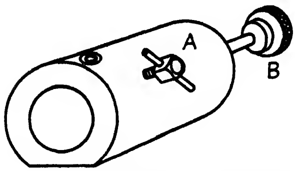


FIG. 66.—Simple design for drilling cross holes in pins. Flattened to prevent turning. Screw *A* holds work, plunger *B* ejects it.

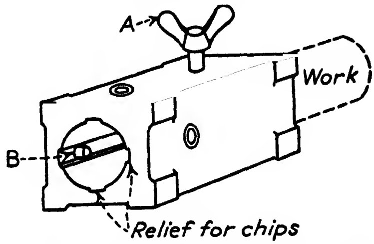


FIG. 67.—Square jig for drilling cross holes. Work held by screw *A* located by pin *B*. Relief grooves for chips add to its usefulness.

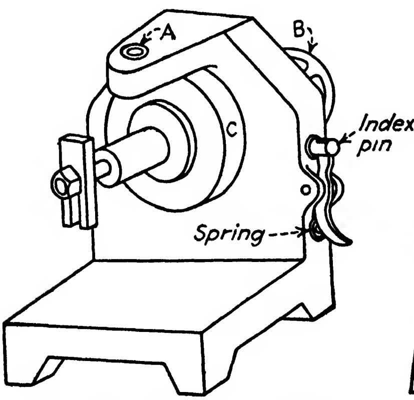


FIG. 68.—Rotary or indexing jig. Bushing at *A*, handwheel *B* turns index plate *C* when index pin is withdrawn. Work is held by hairpin clamp.

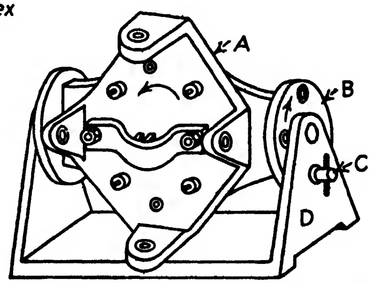


FIG. 69.—Double-acting rotary jig. Work clamped at *A* which revolves on *B*, and *B* also turns in *D*, located by index pin *C*. Good for large work.

With this in mind, it is believed that the average designer of jigs and fixture will obtain many ideas that can be applied to his work in some way or other. In addition to the outline of typical fixtures, which have been taken from actual practice over a period of years, there are many examples of fixtures in use on particular jobs. Many of these can also be adapted to operations other than those shown.

The use of light alloy fixtures, for ease in handling, and of welded jigs and fixtures is also discussed, and examples of practical applications are shown later. These, together with the

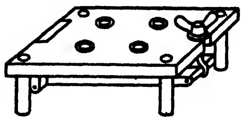


FIG. 70.

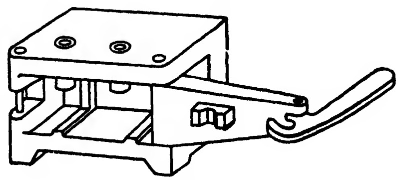


FIG. 71.

FIG. 70.—Table type of jig, made in both large and small sizes. Legs should be larger than slots in drill press table so as to ride over them.

FIG. 71.—Open jig with hook lever locking cam. This style of clamping has many advantages. It will not work loose if well designed.

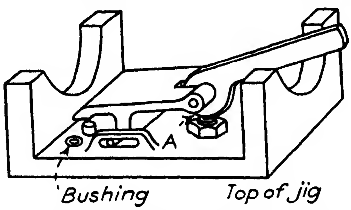


FIG. 72.—Another type of cam for locking work. Movement of cam is usually limited to about 1/16 inch. With an adjusting screw at *A* its scope is increased.

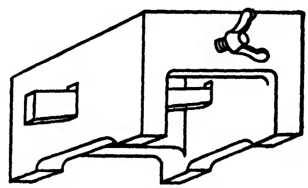


FIG. 73.—Using wedge to hold work up against bushing plate. As with cam lever the amount of movement is limited as taper must not be too steep to hold wedge in place.

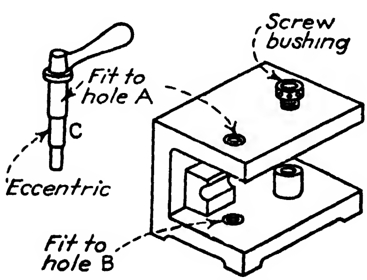


FIG. 74.—Here the work is held by an eccentric pin *C*, with bearings for bushings *A* and *B*. By leaving the pin loose the work can be easily removed.

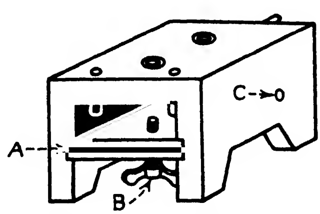


FIG. 75.—A jig with a sliding lid or plate *A*, that carries the clamping screw *B*. Lid stops against pin *C* which projects inside.

many details such as bushings, latches, and other features that go to make up the completed fixture, give a wide variety of designs from which to choose in laying out new or special work.

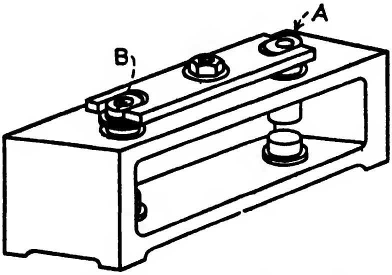


FIG. 76.—Here slip bushings *A* and *B* hold the work and pilot drills. The forked plate forces them against the work.

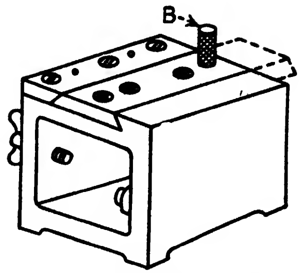


FIG. 77.—Slide carries bushings and pin *B* is used in indexing for different hole locations.

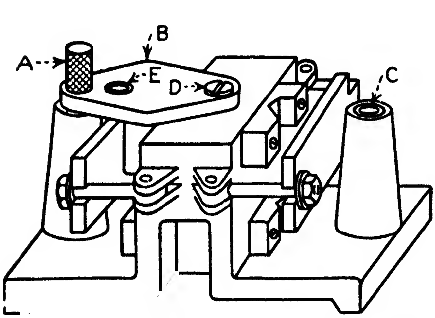


FIG. 78.—Simple form of double jig. Index pin *A* moves with plate *B* when it is swung to the other position at *C*. Plate is pivoted at *D*. The drill bushing is at *E*.

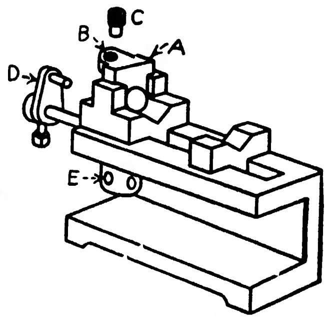


FIG. 79.—Jig for drilling cross holes in round bar stock. Clamping slide *A* carries fixed bushing *B* and slip bushing *C*. Stock is located by stop *D*. Nut *E* locks slide in any position.

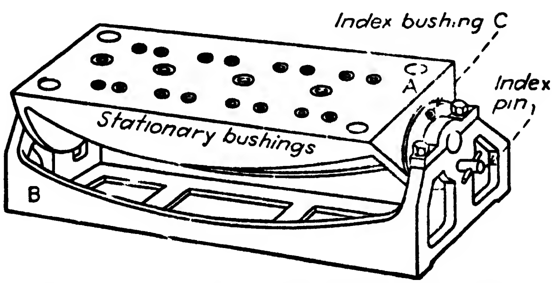


FIG. 80.—Large rotary-type jig with indexing pin. Work bolted to underside of *A* which turns in body *B* and has indexing bushing *C*. Rotary jigs should be balanced for easy handling.

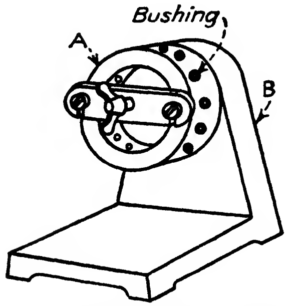


FIG. 81.—A small, simple rotary jig. Drum *A* carries work, and turns in *B*. This is not indexed positively but is used under sensitive drill.

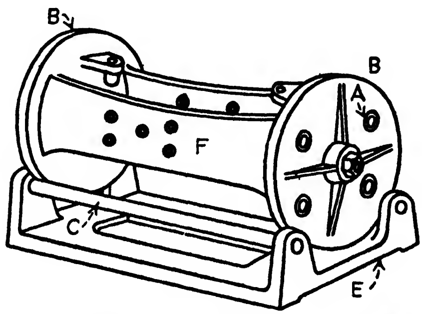


FIG. 82.—Cradle jig. This jig can also drill end holes when removed from cradle. Bushings are at *A* in the ends *B*. These ends roll on bars *C* which are held in base *E*. Cradle is removed for drilling end holes.

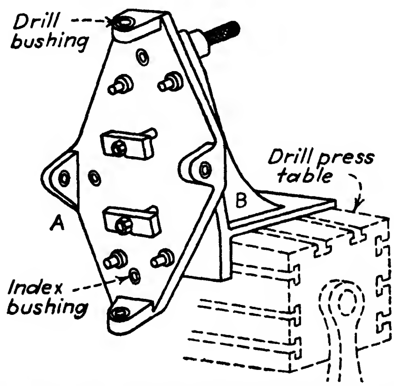


FIG. 83.—This type of rotary jig fastens to the drill press table. Body *A*, supported by angle plate *B*, rotates and is indexed by pin and bushings shown.

The plate or temporary jig shown in Fig. 62 may be found more useful in some shops than its brief caption might indicate. It is located on a casting by means of two or more locating pins and is held by a clamp while the holes are being drilled. Sometimes this is all that is needed.

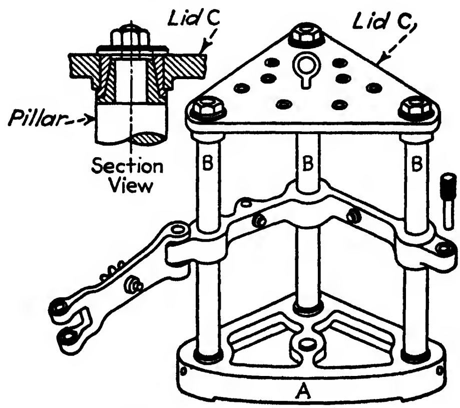


FIG. 84.—Pillar jig which saves weight for large work. Consists of base *A*, three pillars *B* and lid *C*. Detail shows how tapered bushings on pillars make it easy to remove and replace plate.

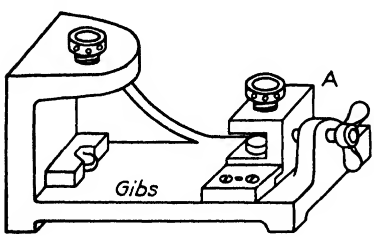


FIG. 85.

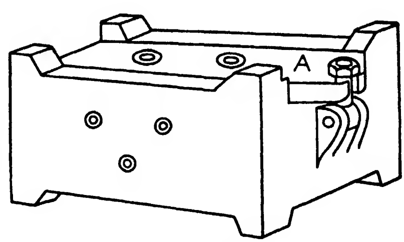


FIG. 86.

FIG. 85.—Double-acting jig with V's and screw bushings. Work is centered by two V's. One V is carried in slide *A* which also has a screw bushing. Both screw bushings are used to hold work on its seats.

FIG. 86.—A box jig with swinging lid. Box type of jig. Lid *A* is guided between sides and locked by a swinging bolt.

For small jigs the plate *A* is often made of steel, and instead of having bushings this plate is drilled out to suit the drill to be used, and then it is casehardened, after which the holes are lapped and the locating pins driven in place. They are more frequently made of cast iron, in which case the locating pins are hardened and the standard form of bushing used.

The designs can all be varied to suit conditions.

CHAPTER XI

PNEUMATIC FIXTURES FOR HOLDING WORK

The illustrations show part of a line of quick-acting fixtures, designed for profiling, milling, and drilling metal parts of a well-known machine. *It had been found that, in the fixtures used previously*, more of the operator's time was often taken in clamping and unclamping the work than was consumed in the actual cutting operations.

There is nothing startling in the design of these fixtures except, perhaps, a little more tool work in the making of them than there would have been if simple screws, clamps, or eccentrics had been used to hold the work in place. But the great saving in time and consequent cost of manufacture brought about by the use of fixtures of this nature should not be overlooked. The line of fixtures shown herewith is mostly for cutting brass, and, as the cuts are made very quickly, the operator will spend the greater part of his time in placing and removing the work.

The first fixture (Fig. 87) is a profile fixture for the cut, extending from A to B; the cut is about 12 in. long and not very heavy generally, excepting at the top part, a distance of about 5 in., where sometimes the castings come a little heavy at this place. This fixture consists of a cast-iron base 1 in. thick held to a profile-machine platen by two fillister-head screws. On this base, held by three screws, is a machine-steel form plate $1\frac{3}{16}$ in. thick, which is carbonized and hardened on the tapered form surface at AB, on which the taper roll of the cutter arbor shown bears; this is made taper for adjusting the cut as the cutter is ground.

The work is slid under this form plate, dropped over and against the two locating pins at the bottom edge, and located sideways with a knurled screw forcing the work against the pin, which is cut away to fit the corner in casting as shown; then, quickly touching the valve lever, the work is clamped.

The fixture previously in use had five $\frac{3}{8}$-in. screws for clamping the work. At the rate of 65 cts. per hundred for the making

of this cut, an experienced man, by working very hard and pushing the job as much as possible, was enabled to make $2.80 to $3 per day of 9 hr. This was replaced by the five $\frac{3}{8}$-in. screws with the small plungers as shown, worked by compressed air.

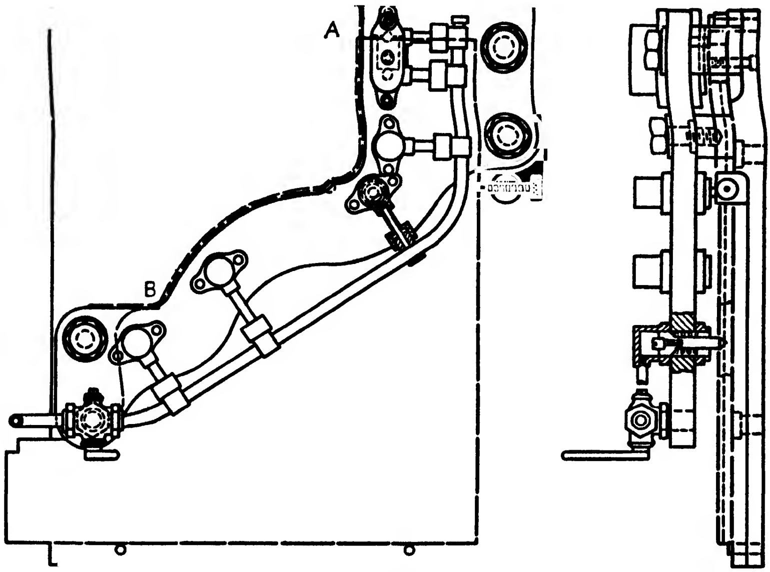


Fig. 87.—Pneumatic fixture for irregular work.

As they were made to clamp close to the working edge, they were made small, $^{13}\!/_{16}$ in. diameter, to clear the profile spindle, and making them small naturally gave very little pressure, but, in a profile cut of this nature, the pressure of the cutter is nearly all sideways. So the plungers were made with a pointed end

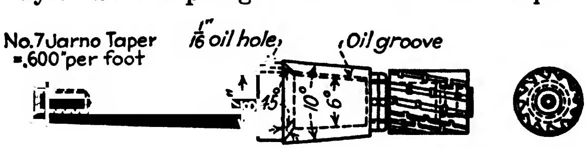


Fig. 88.—Arbor and cutter for profiling.

like a center punch, and, as this point enters the work about $\frac{1}{32}$ in., there was no trouble whatever in holding the work, the secret of it being the pointed clamps.

With the pneumatic fixture, the operator could make the same pay with the price lowered to 30 cts. The air pressure was sup-

posed to be 80 lb., although at that time the air plant was small and the pressure would sometimes get down to 50 or 60 lb. Figure 88 shows an arbor for cutters used to follow a form in profiling.

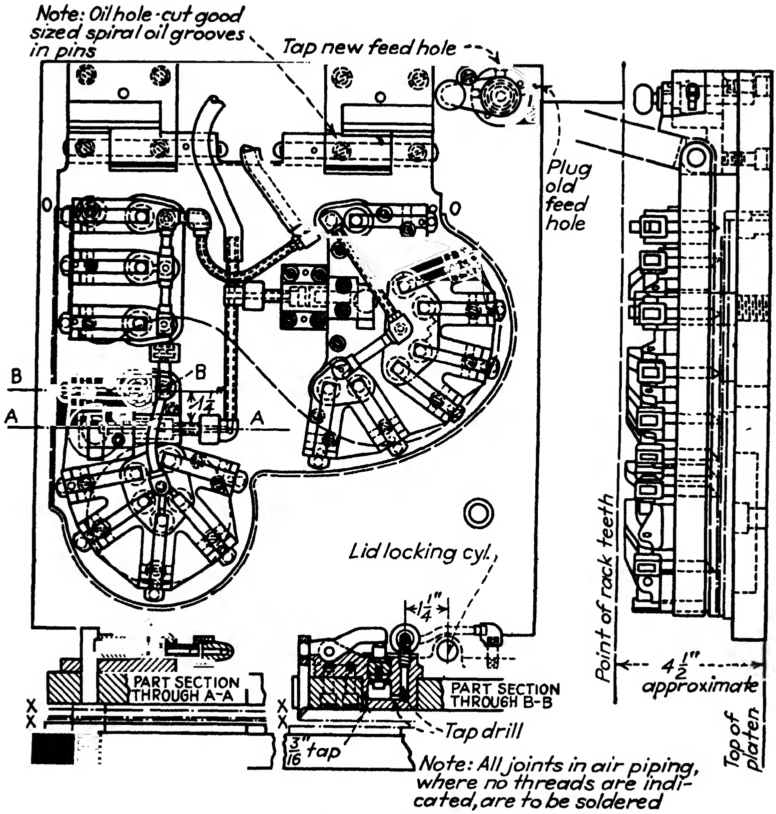


FIG. 89.—A somewhat complicated pneumatic fixture.

Holding a Weak Piece of Work.—Figure 89 is a profile fixture using a form cutter for the cut on the surface marked XX in section and extending around from O to O on a brass-plate casting of a shape as shown by the dot-and-dash line. This casting is narrow and weak at and near the ends OO. The fixture has a cast-iron base $1\frac{1}{4}$ in. thick, which is screwed to the profile platen. A machine-steel form plate with hardened straight-faced contour, used for guiding the cutter, swings on hinges to admit of placing

the work, these hinges being at the right-hand side of the operator. This form plate is further guided and controlled by having two slots $\frac{1}{2}$ in. wide, which pass over, fitting sideways and bearing against the shoulder of the hardened-steel posts, as shown at *AA*. Inserted into clearance holes in this form plate are several bronze castings, being held to the form plate with fillister screws.

These castings have a number of $\frac{11}{16}$-in. holes in them for operating the air pistons, which work through levers, as shown in section view. This also shows the center-punch points and how they get close to the outer edge of the work. In addition to the cylinders operating the clamping points, there are two other $\frac{5}{8}$-in. cylinder castings which operate the lock bolts holding the form plate to the base of the fixture, as shown at *AA*. The clamping cylinders are all connected by holes and piping to a small piece of rubber tube which leads to the valve in the corner of the base of the fixture. The two form-plate locking cylinders are connected to another piece of rubber tube, which also leads to the valve. The form plate, being heavy, is raised and lowered for the admission of work by a very simple air hoist, which is not shown. The work which is shown finished, in a dot-and-dash line, has a hole at *AA* which fits over the locking post and is swung against the pin at *O* for locating, the form plate being up at this time. Touching the air-hoist valve, the form plate quickly and lightly drops to position. Next, touching the valve on the corner of the fixture first admits air to the locking cylinders and, second, with the same movement, admits it to all the clamping cylinders holding the work. To remove work, touch the valve on the corner of the fixture; then touch the hoist valve and take the work out.

In the fixture previously used, the work was held by clamps and screws, without any lid, being slid under the form plate and clamped; with this style of fixture, \$1.80 per 100 was paid for the making of this profile cut. With the fixture as shown, using air, the price paid is 90 cts. per 100; and this enabled the same man to make the same wage as before.

Another Pneumatic Milling Fixture.—One of the milling jigs used by the Cincinnati Milling Machine Co. is shown in Figs. 90 and 91. The first shows the general arrangement of the cylinders and jaws, while the latter gives details of construction.

There are six cylinders, three on each line of air pipe, and, in addition to cutting out either set of three, each cylinder has a separate cutout in the shape of a plug cock. The pistons each have four packing rings.

The operation of the vise is as follows: Air at 80 lb. pressure per square inch is admitted to the chamber *A* through the pipe *B* and cock *C* and forces in the piston plunger *D*. Motion is transmitted to the movable jaw *E* through the link *F*, causing the jaw to clamp the work securely.

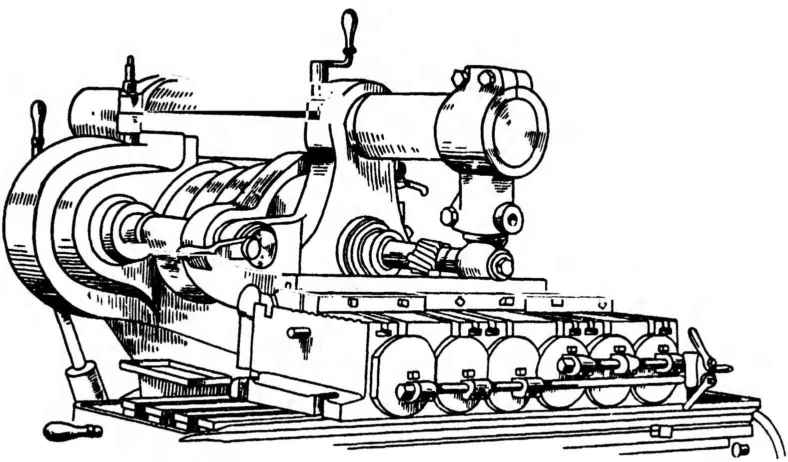


Fig. 90.—A six-cylinder pneumatic fixture.

To release the work, the air cock is closed, and the pressure against the piston is relieved by the air escaping through the exhaust opening *G*; the piston and jaw are then returned to normal position by the springs *H*. *I* is a cast piece serving as a cover for the working parts of the jaw.

It will be noticed from the construction of the air cock that, depending on the size of the work, either three or six jaws can be operated. *J* is the back, or fixed, jaw. It is fastened in the slots *K* and can be adjusted back and forth. Hardened pieces *L* are provided for bearing against the work. The setscrews *M* are carried in the backing strips *N* and are tightened against the fixed jaw to give it greater rigidity. This work is positioned lengthwise against the adjustable stops *O* and is supported by the bearing strips *P* and the blocks *Q*, which latter are provided

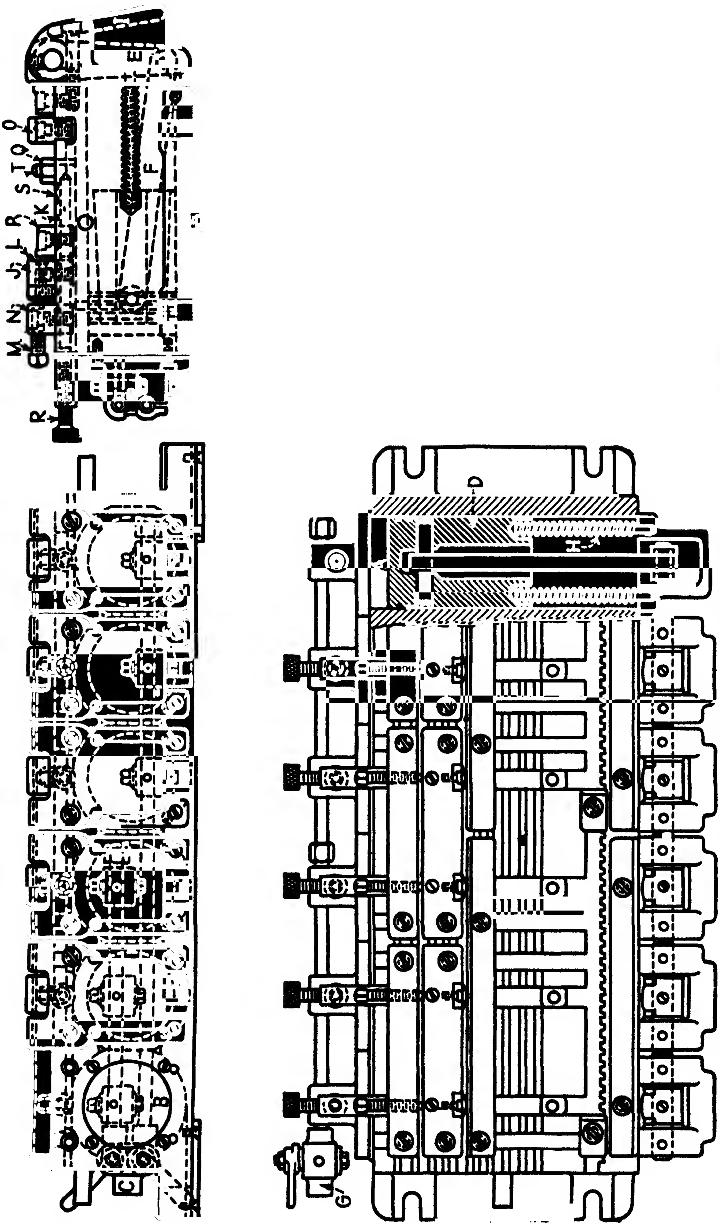


FIG. 91.—Details of the same fixture as shown in Fig. 90.

with pins T, the height of which is adjustable by the screw R and pin S.

This vise, with its various adjustments, covers a wide range of adaptability, and many pieces of varying size can be handled in it.

One point to be borne in mind regarding pneumatic fixtures is that the work must be timed so as to insure the completion of a cut

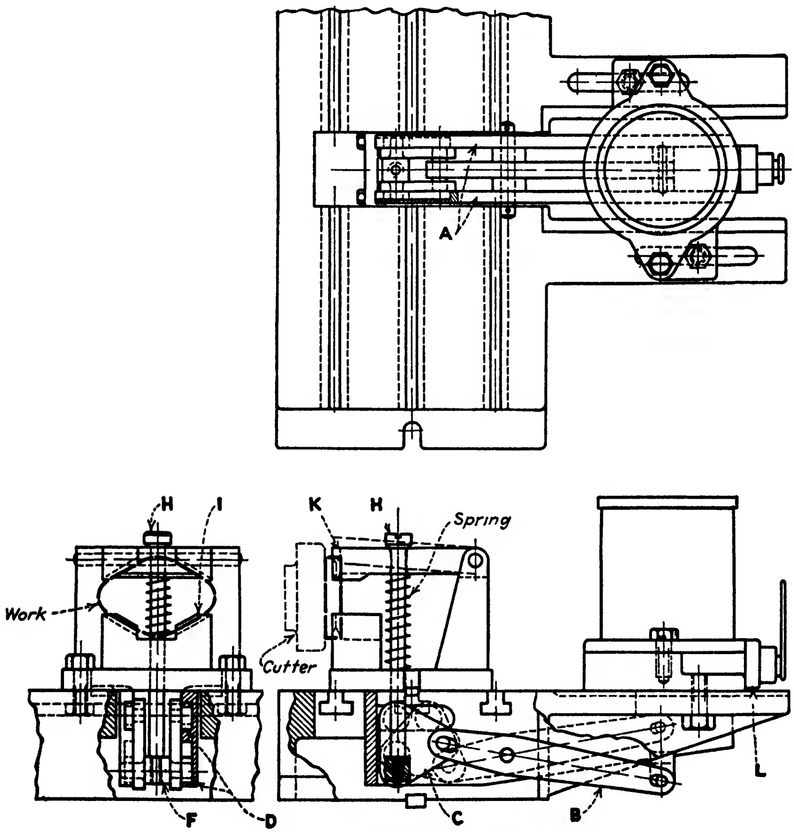


FIG. 92.—A positive air clamp.

before the machinery is shut down for the day. Otherwise the almost inevitable leakage of air from the fixture will release the work in the machine, and the piece will have to be done over, as it is practically impossible to replace the work in exactly the same position in the fixture. The device that follows tends to overcome this difficulty.

Positive Pneumatic Clamping Device.—For holding work to be face milled with a carbide-tipped cutter, it was considered necessary to design an air-operated clamping device which would not open should the air pressure drop during a cut. Since the development of this simple clamping device, shown in Fig. 92, some 20 simple fixtures have been used with it.

The air cylinder, valve, and clamping mechanism are mounted on two parallel plates *A*, which can be moved forward or back to suit conditions. This is done by loosening the nuts on the

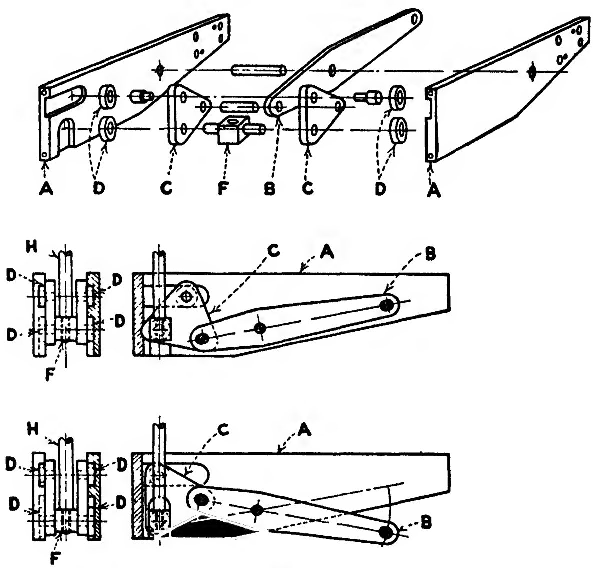


FIG. 93.—Details of bell crank and connections.

two bolts engaged in slots in the base. The toggle *B* connects the piston rod with the wrist plates *C*. These two triangular plates float on the four rollers *D*, two of which travel horizontally and the other two vertically in slots milled in plates *A*. Trunnion *F* serves as an axle for the rollers traveling in the vertical slots and is tapped for the drawbolt *H*. The holding fixture for the work consists of the stationary jaw *I* and hinged jaw *K*, which is operated by the drawbolt.

In operation, the air valve *L* is opened to admit air above the piston. It then moves the piston-rod end of toggle *B* downward. As the opposite end of the bell crank moves upward, the

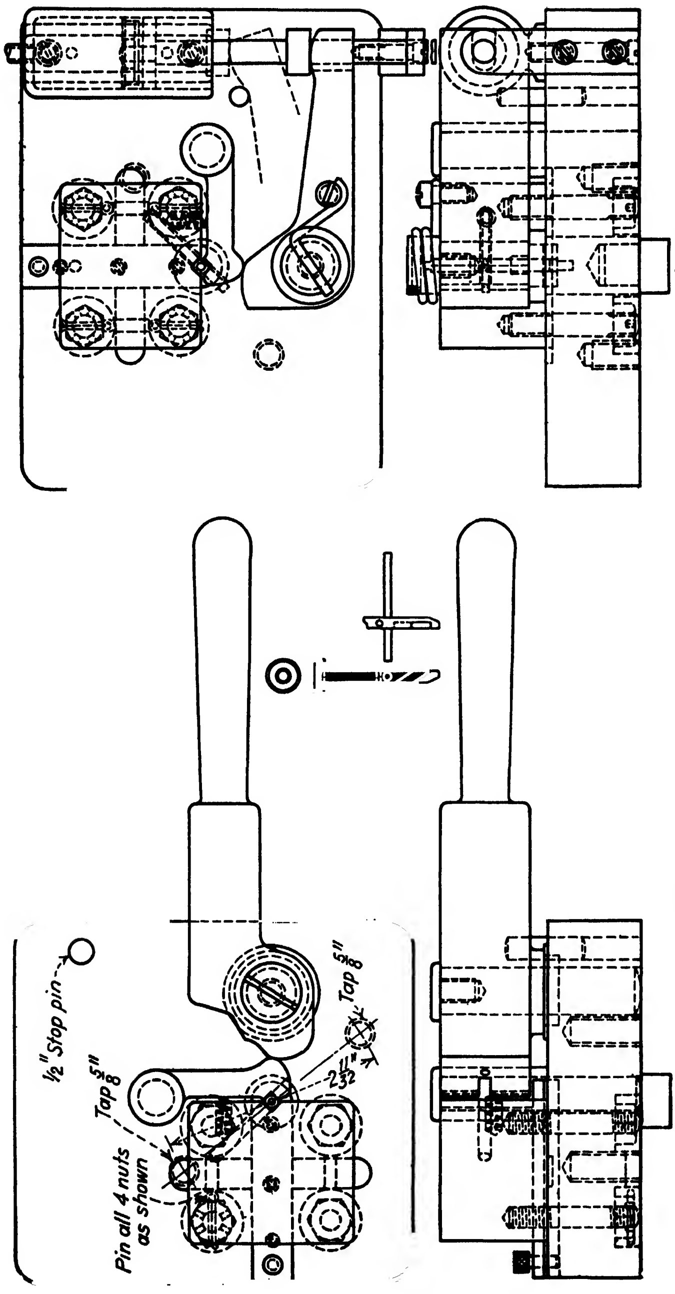


Fig. 95.

Fig. 94.

Figs. 94–95.—Changing a hand fixture to operate by air.

wrist plate is rotated counterclockwise, bringing down the draw-bolt and clamping the work. The rollers in the horizontal slots are now over and in direct line with those in the vertical slots. In this position, the mechanism is locked, and the clamping jaw cannot become loosened should the air pressure drop.

In Fig. 93, details of the bell crank and the wrist-plate mechanism are shown at the top. The mechanism in the unclamped position of the work is shown in the center and in the clamped position at the bottom. In this last view, it will be seen that the wrist plate is locked and that the work will remain clamped independently of the air pressure in the cylinder. Admitting air under the piston releases the work.

Changing a Hand Fixture to Use Air.—Figures 94 and 95 show an example of a fixture both before and after taking the air. In Fig. 94 is a fixture for riveting the round key cup to the round-shouldered end of a square-steel key. This key has a slot milled near the bottom end and also a hole with a pin projecting from it near the center, making it weak at this lower end, as will be seen by looking at the detail of this key shown at the side of Fig. 95. These keys, being weak, must have a powerful clamping pressure applied to them to prevent them from springing by the action of the riveting machine forcing them down on their lower end. These keys are held in a V with a V-shaped lever, being clamped with a cam lever about 10 in. long. It is a simple movement to operate this lever, but it is tiresome and slow in comparison with the mere touch of an air valve.

Figure 95 shows how this fixture was improved, by putting a small air cylinder in one corner and connecting its piston rod to a cam-shaped lever. It then required but a light touch of the valve lever to clamp or unclamp the work. This increased the output and also insured the same clamping effect every time, preventing any springing of the keys brought about by the operator's not putting sufficient clamping effort on the cam lever, shown in Fig. 94.

Air Applied to Large Fixtures.—Figure 96 shows how air was applied to several large jigs for drilling brass cabinet sides. The outline of one of these jigs is shown in a faint line, but it does not show any of the 13 bushings in the top or lid of this jig, or the four bushings for the base holes in the cabinet side, located

in the back side of the jig. There was also one bushing hole in the side opposite the lid hinges. These 18 holes are all drilled simultaneously on an automatic multiple-spindle drill press. This jig originally had five knurled-headed screws in the lid for clamping the work and also had screws in the lid-locating posts, which are fastened to the base; these screws clamped and unclamped the lid to the base of the jig, by a quarter turn. When using these screws, $1.25 was paid for the drilling of 100

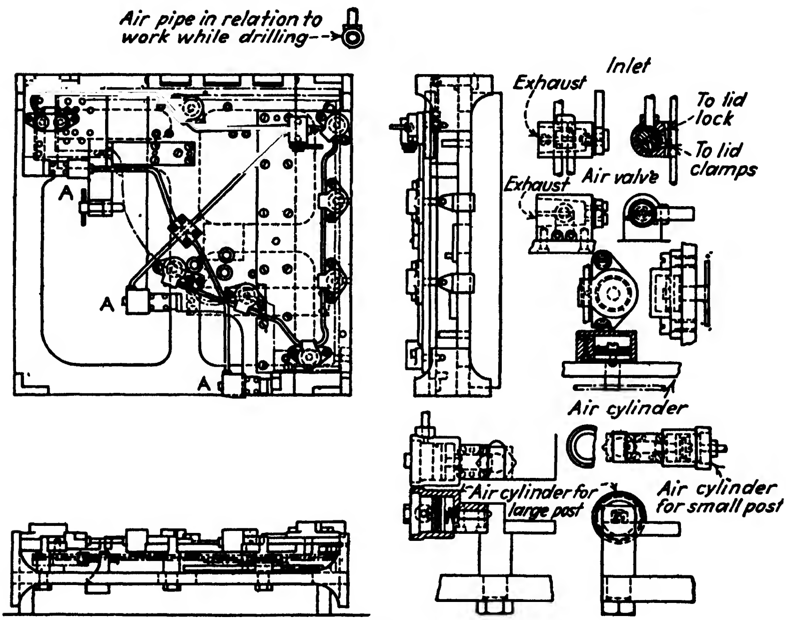


FIG. 96.—A large air-operated fixture.

cabinet sides; but after applying three air-lid locks and the nine air-clamping cylinders as shown, which all work with only a touch of a valve lever, the price was cut to 52 cts. per 100, with the same man on the same machine earning the same wages in each case.

In these drill jigs, a standard cast-bronze cylinder casting was used, being faced off on the end, which is screwed to the top of the jig lid, this faced end having a projection in which is milled a $\frac{1}{4}$-in. slot, round at the bottom; in this slot is the $\frac{3}{16}$-in. outside-diameter, brass air-supply tube, which is twined around any cylinder in place like a string of putty and is then punctured

with a $\frac{1}{32}$-in. hole and packed around with soft rubber, the connection being held airtight with the two fillister-head screws which also hold the cylinder. The details of the clamping cylinders, lid-locking cylinders, and the air valve are all clearly shown in the sectional detail. These clamping cylinders, lid locks, valve, and piping are all on the top of the lid jig; the valve is in one corner and is connected to the air-supply pipe by a rubber tube.

To operate this jig, place the cabinet side in position, lower the lid, and touch the valve lever. This allows air to pass through

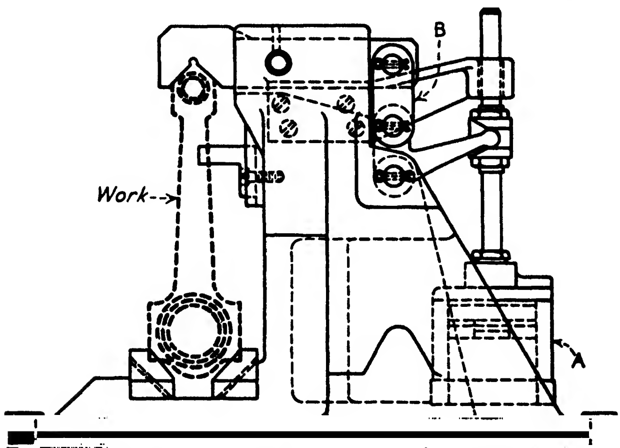


FIG. 97.—Clamping connecting rods by air.

the line of pipe to the three lid-locking cylinders AAA and with only the one movement allows air to pass through the other line of piping connecting the nine clamping cylinders. The jig is then ready to roll to position under the 18 revolving drills. A backward movement of the valve lever unclamps the work and then unlocks the lid.

These fixtures are rapid; hold the work well; and in any of the departments where fixtures of any nature operated by air are placed, the workmen like them, and the foremen naturally become so enthusiastic about them that in some cases they clamor to have all fixtures operated by air.

Air Fixture for Connecting Rods.—Automobile connecting rods are milled in an air-operated fixture shown in Fig. 97. This fixture has an air cylinder built into the base at A. The

movement of the piston is transferred to the toggle arm *B*, which in turn operates the clamp. The large end of the work is located in a stationary V block, and another V block is machined in the clamp to hold the smaller end. The fixture can be arranged to suit different sizes of connecting rods by changing the lower V block and applying a clamp.

INDEXING FIXTURE FOR CONNECTING RODS

The fixture shown in Fig. 98 was designed by Harry Blenman for milling the crank boss and wrist-pin boss of two airplane-

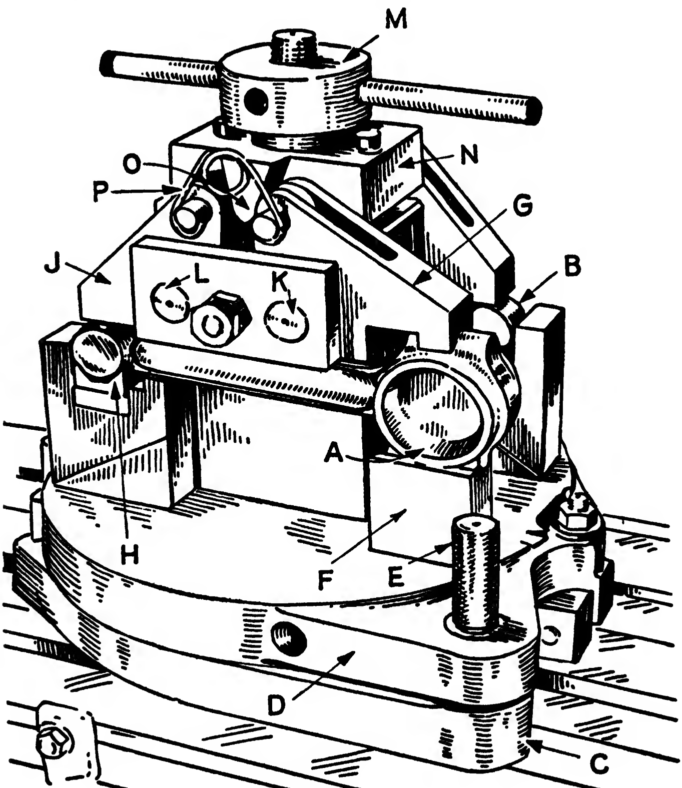


FIG. 98.—Equalizing clamp for two connecting rods in reverse position.

engine connecting rods simultaneously on a universal milling machine. Rods *A* and *B* are set in the fixture so that the crank end of rod *A* and the wrist-pin end of rod *B* are adjacent to the

cutters on the arbor. When indexed 180 deg., the crank boss of rod *B* and the wrist-pin boss of rod *A* come to the position shown in the drawing so that once the cutter setup with the correct spacers for milling the sides of the bosses has been set up on the arbor, it is not necessary to change the setup, except for sharpening the cutters.

The fixture consists of base *C* which is bolted to the table, the swiveling plate *D*, and index pin *E*. The rods are clamped in

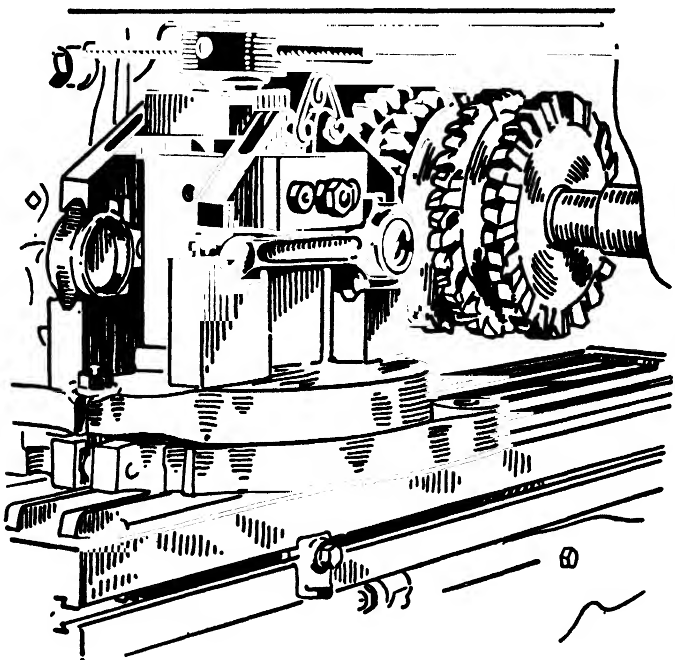


FIG. 99.—Gang cutters and the work in fixture.

solid V blocks *F* and *G* at the crank boss end. The wrist-pin ends of the rod rest in self-adjusting V block *H*, which align the rod when pressure is exerted on clamp *J*.

Clamps *G* and *J* pivot about pins *K* and *L*, respectively. Pressure is exerted on the clamp by the nut *M* when it is screwed down against block *N* which has tapered arms *O* that spread the arms *G* and *J*. The spring *P* prevents the clamps from dropping when nut *M* is loosened to remove and apply rods.

The wrist-pin and crank-boss faces of these rods must be milled parallel with each other. This fixture does this work accurately to the tolerances required for the airplane engine.

Prior to the use of this particular fixture, a solid one was used for milling one rod at a time. After this fixture was designed and built, necessitated by a set-up in the production of the engines, production of the rods was increased 50 per cent per milling machine.

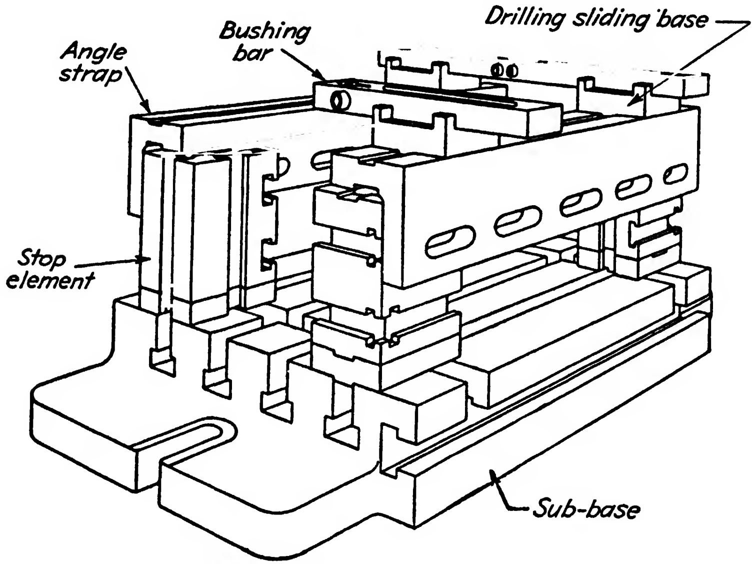


FIG. 100.—General arrangement of drill jig.

A fixture similar to the one described in Fig. 99 is used on duplex milling machines for milling both sides of the crank bosses simultaneously, after which the table advances for milling both sides of the wrist-pin boss, simultaneously. Both types of fixtures are now being used.

BUILT-UP JIGS AND FIXTURES

A system of building jigs and fixtures by combining standard units in various ways has been devised and patented by Wharton & Olding in England. There are 22 basic elements, and each is made in three sizes, which can of course be increased or varied to suit special conditions. Instead of designing a fixture in the

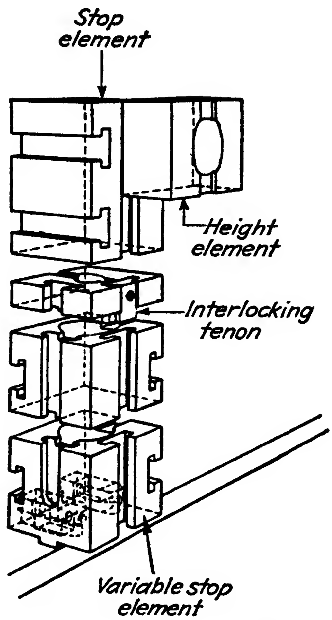


FIG. 101.—The stop elements used.

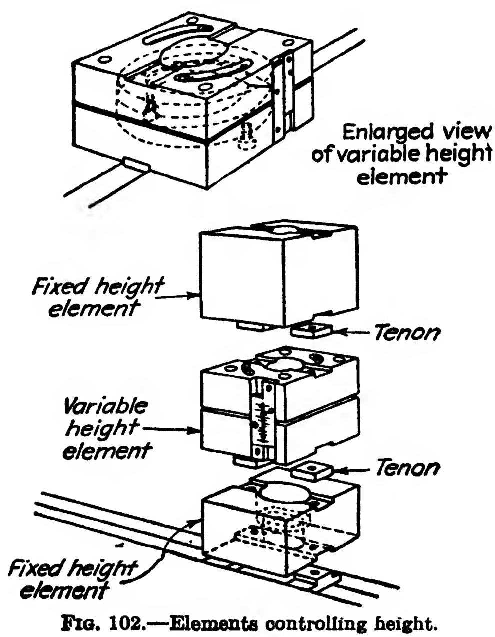


FIG. 102.—Elements controlling height.

usual way, the designer combines as many suitable elements as necessary in the form desired.

The various elements are duplicated in plastics, and these lightweight elements are assembled around a model of the part to be

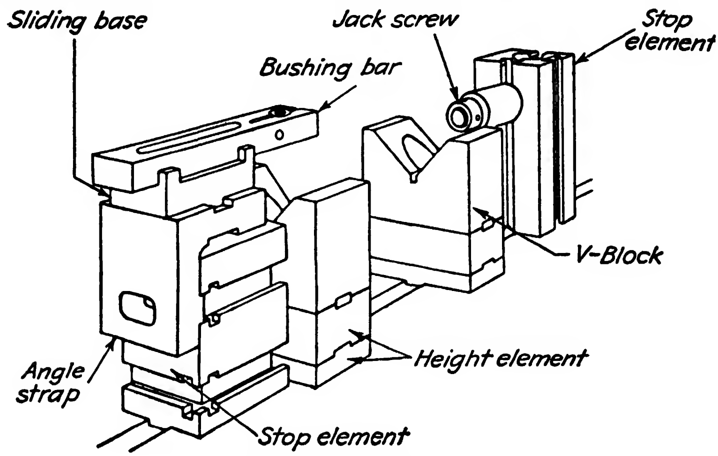


FIG. 103.—How V blocks are used.

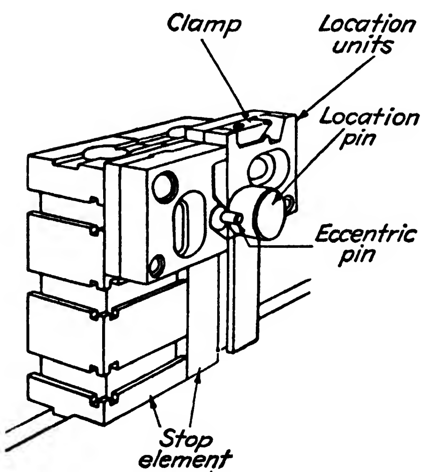


FIG. 104.—Units used for location.

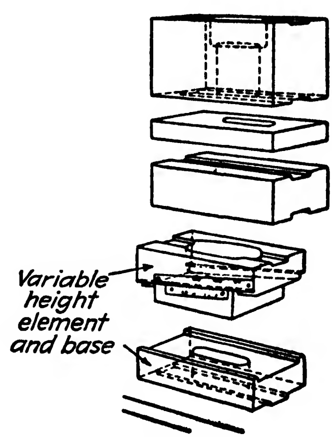


FIG. 105.—The height elements.

machined just as the elements themselves will be placed when the form and arrangement are finally decided upon.

A book of reference drawings helps to designate the parts used by number, and an instruction sheet of assembly is prepared.

The layout is then photographed from several angles, including a plan view as a guide for assembling the elements in the shop. When the fixture has served its purpose, as on small production work, it is dismantled and the elements returned to the tool storage. The photographs are then filed to facilitate duplicating the set-up at any future date.

Interchangeability is secured by having suitable tenons and slots machined in the different elements, as can be seen from the illustrations. The fixtures can be expanded in all directions.

Three sizes have been made to date. The units are $1\frac{1}{4} \times 1\frac{1}{2}$, 2×2, and 3×3 in., being designed for small work. They can be made in any convenient size best adapted to the class of work on which they are to be used.

Figures 100 to 105 show an arrangement of a drill jig, the *step* elements, the *height* elements in two types, also the use of V blocks. These are explained in considerable detail for each of the six elements.

Section 4

METHODS FOR PRODUCTION MILLING

Milling Contours on Connecting Rods by the Bridge Method.—A milling fixture for roughing the contour of articulated rods for airplane engines is seen in detail in Fig. 24. The rods are

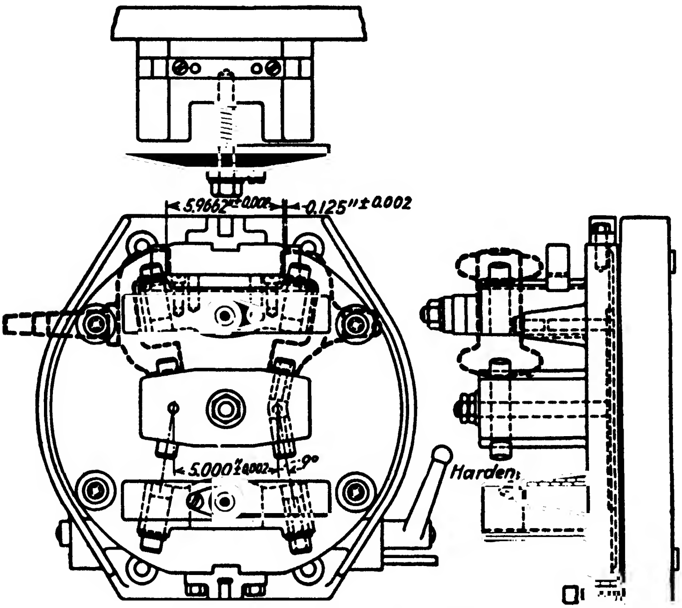


FIG. 23.—Another type of fixture.

clamped in a hinged section of the fixture, which is operated by two hardened cams which ride over a roller. The contour of the cam is reproduced in the work. Two pieces are held at once, and the milling is done first on one side and then on the other.

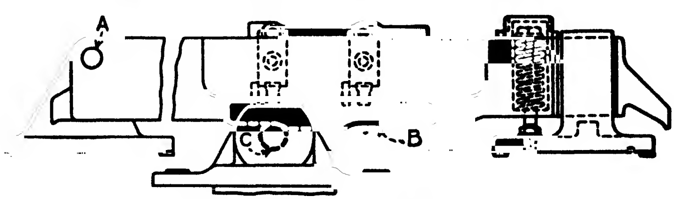


FIG. 24.—Fixture for milling contours.

The fixture obviated the necessity for form cutters and was better in every way. The fixture body is hinged on the pin *A*, which is mounted on a bracket attached to the machine table. The other end of the fixture is guided by a U-shaped bracket

which permits a limited vertical movement. Two helical springs hold this end of the fixture down and insure a firm contact between the cam B and the roller C. The fixture also has a trough built all around it to prevent the cutting lubricant from splashing on the operator. The work is moved up and down as the cam passes over the roller, and the cutters shape the work to match the cam. This type of fixture is known in the gun shops as a "bridge" fixture.

Slide-milling Fixtures.—A steel piece used on a textile machine is shown in Fig. 25. It is finished all over, and the dimensions A, B, C, D, and E have to be correct; the location of the holes F, G, and H must also be exact.

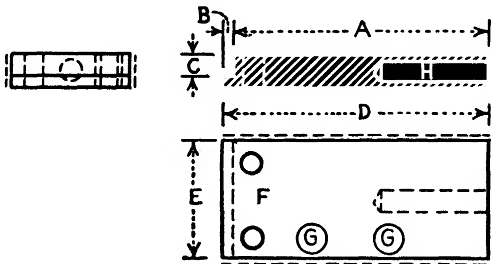


FIG. 25.—A piece finished all over.

The first operation is to finish the two long edges indicated by the heavy dotted lines. This is done on the miller by running long strips of steel, having the correct thickness, between two cutters set the proper distance apart. These strips are then cut into pieces long enough to allow the necessary finish. The end E is next milled at right angles to the finished sides. Then the shoulder and opposite end are milled.

The ends are trimmed, and the shoulders cut on four pieces at once in the fixture shown in detail in Fig. 26. It consists of a cast-iron base plate A with projections at B. These projections are shaped to receive the four special steel clamps C, which are pivoted on the pins D. The steel plates E are screwed to B to serve as guide plates for the pieces F.

The top of each projection is milled out wide enough to allow two pieces to be inserted side by side. The screws G operate the clamps, and the ends butt upon the hardened-steel pins H. Slots are provided to clamp the base plate to the miller table, and keys are set into the bottom to line it up with the T slots.

The half-round openings J are made in the casting to enable the operator to get his thumb under the pieces F and to insert or take them out in an easy and convenient way.

The milling is done with a gang of three cutters having the correct width and relative diameter; these are run between the two pairs of slides, thus cutting out the shoulders and also trimming them to the proper length.

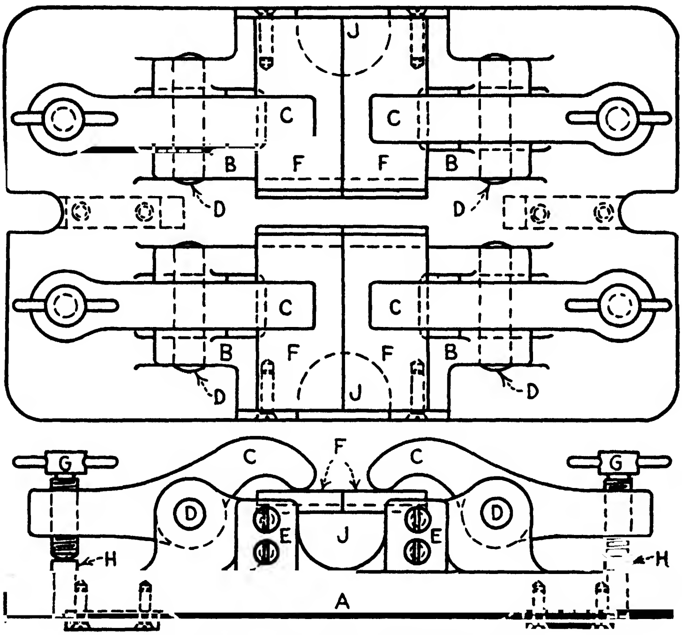


FIG. 26.—Trimming four pieces at once.

Holding Two Pieces at Once.—Figure 27 shows a fixture for making a hinge cut on each end of a curved, brass cabinet lid of different lengths, the longest lid being about 19 in. The fixture is designed to do two lids of the same length at a time, both hinge cuts being made simultaneously with a double-head mill, and the cutters being double interlocking with herringbone teeth, this being done to make a smooth cut.

As the fixture is made to do different lengths of lids, it has two clamping heads, made to slide toward the center of fixture, guided by a tongue, and held down to the cast-iron base plate by two bolts sliding in the T slot in the base. On these clamping

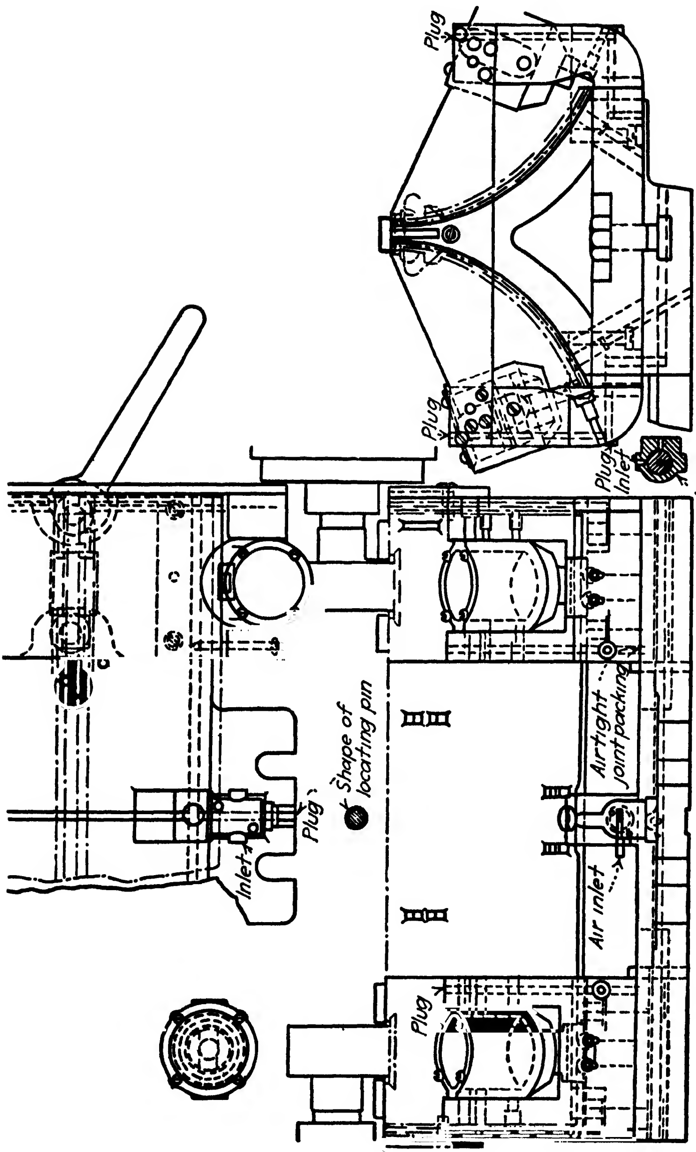


FIG. 27.—Double air-holding fixture.

heads, a machine-steel forging, planed to fit the contour of the lids to be milled, is fastened by screws. These lids come against casehardened heads, formed on this forging at the top. This forging is stiffened by a plate, which is tongued and screwed to it and further fastened to the clamping head at each side.

Each clamping head in a recess cored in each side has a cast-bronze cylinder of 2⅛-in. bore, fitted with the usual leather-cupped packed piston, carrying a clamping plunger 1¾ in. wide at the bottom, which is beveled, forming a wedge between the work to be milled and two hardened pins opposite. The work, which is shown clamped in the fixture in a dot-and-dash line, is previously milled on the lower and upper edges.

To release this work, simply touch the valve lever, shown on the base in front at the center which raises all four wedges, this being all there is to the clamping or unclamping of these two cabinet sides. The air-connecting holes are all made by drilling through the base and heads leading to the four cylinders; to the uninitiated, it is something almost uncanny to see a fixture of this kind clamp work without any visible connecting link. Attention is called to this peculiar method of clamping for such a heavy cut as this, as, from the end, it seems as though a cutter would push the other side away; but, taking into account the point at the clamping wedge it would have to swing from, it will be seen that it only holds the tighter.

Holding Tie Bars of Different Lengths.—Figure 28 is a fixture designed to mill the ends of two cast-iron tie bars at one time and also to mill bars of different lengths. The drawing shows, by a dot-and-dash line, two of the longest bars clamped in position. This fixture has a cast-iron base carrying four movable cylinders in which are the usual pistons as seen in the section, each piston having a steel plunger pointed and hardened on the end, which pushes against a lever that is keyed to a forged tool-steel shaft ¾ in. in diameter, swinging in bearings and having on the other end another lever forged on it. This lever has a knife-edge hardened and bears against the work to be milled.

The work to be milled is supported at each end by a machine-steel, carbonized, and hardened block, which is adjustable for the different lengths of tie bars to be milled and is located with a tongue and held to base by a single bolt. This bearing block is easily removed for other shapes suiting different work. The

valve in this fixture is on the base and is connected to the four cylinders by short pieces of rubber tube which are joined to connections leading to a hole in the base.

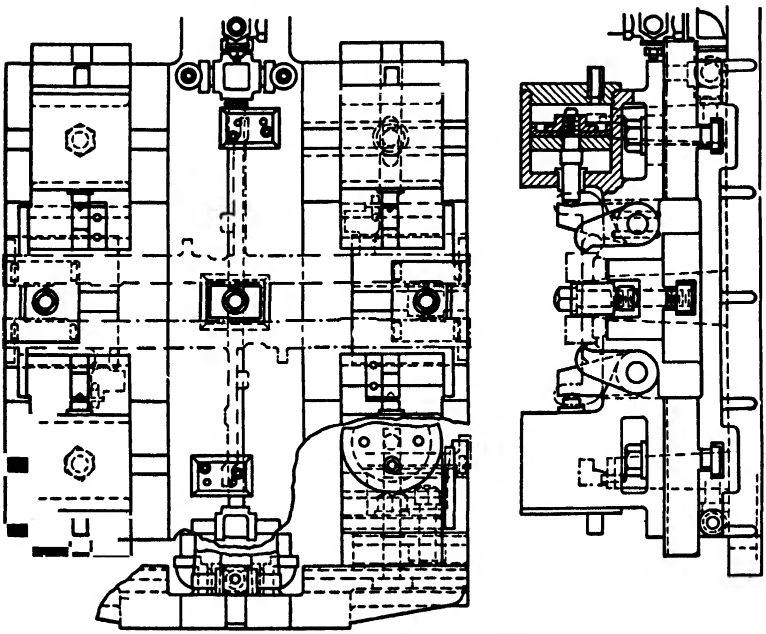


FIG. 28.—Another pneumatic fixture.

These cylinders are made large, 3 in. in diameter, as the cut is heavy, and the force of it comes directly against one of these bars, which must be counteracted by the air pressure. A single touch of a lever clamps these two tie bars, and a touch of the same lever releases them. Other air-operated fixtures are shown elsewhere.

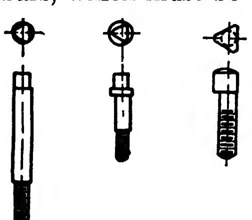


FIG. 29.—Triangular bolt heads.

A Group-milling Fixture.—In the ancient city of Przemyśl, Poland, many shops were engaged in reconditioning machines of various kinds, all of them supplied with improvised replacements. The most frequent substitute parts are screws and bolts—inconspicuous replacements, were it not for the trick of putting triangular heads on them, as in Fig. 29. Perhaps the want of square or

hexagon bars explains the triangular heads, for round bars only are used—or is it more economical to machine three faces instead of four or six?

That ingenuity is not wanting in Przemyśl is evidenced by the fixture illustrated in Fig. 30. The base *A* has a sleeve retained within it by a flange and a threaded collar, so that it can be rotated and locked in position by the index pin *B*. To the flange is attached the plate *C*, having a triangular opening at *D*. At the lower end of the sleeve is attached the three-legged spider *F*, the position of its legs corresponding with the corners of the

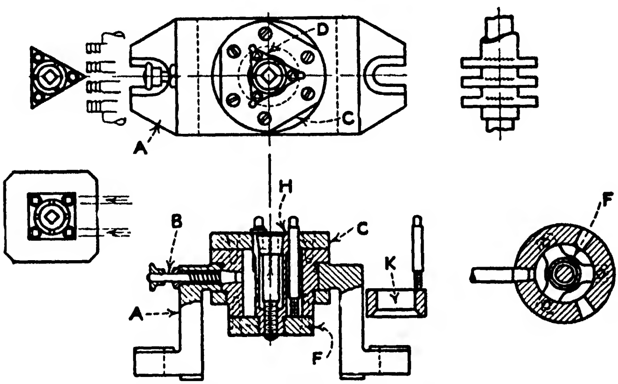


FIG. 30.—Bolts are held by expanding collet.

triangular opening in plate *C*. The collet *H* is screwed into the spider and is expanded by a screw having a tapered head.

Screws to be milled are inserted between the head of the collet and the corners of the triangular opening in plate *C* and are wedged into the corners by expansion of the collet being securely held in alignment and spacing. The work is prevented from moving downward by its lower end resting upon the legs of the spider. In the case of shorter screws, the ring *K* is inserted into the sleeve, the lower ends of the screws resting upon it. Where screws have integral collars under the heads, the collars rest directly on the plate *C*. The top of the fixture is free from all projections, and ample clearance for chips is provided by the openings between the spider legs.

For milling triangular heads, the cutters are arranged as shown in the upper right-hand corner; one face of each of three pieces is milled at a time, the fixture being indexed for the other faces.

The novelty of the fixture lies in the use of the collet for group clamping. By arranging the cutters as shown in the upper left-hand corner, hexagon heads can be milled. For square or octagon heads, plate *C* and the spider *F* are replaced by a plate having a square opening and a spider having four legs as shown at the left center, the sleeve being provided with the correct number of holes for indexing.

Milling in Two Planes.—In machining the beds for printing presses of the job type, one of the particular points is to get the angular surfaces *A* (Fig. 31) of the tracks for the ink rollers in correct relation to the seats *B* for the feet of the brackets of the

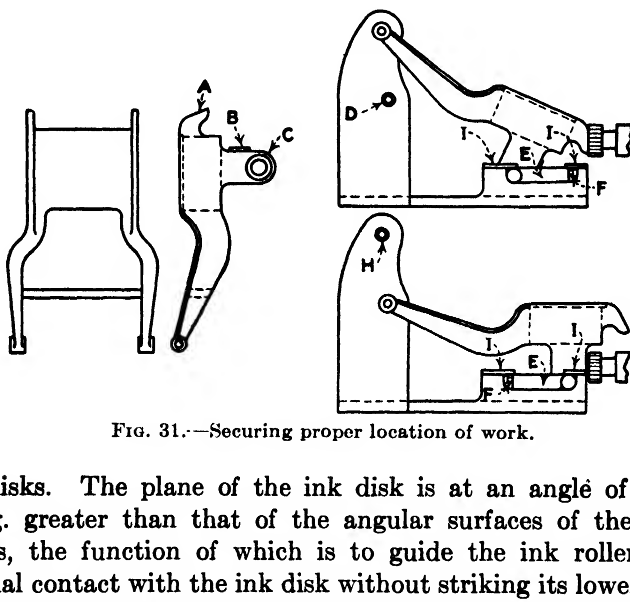


FIG. 31.—Securing proper location of work.

ink disks. The plane of the ink disk is at an anglė of about 5 deg. greater than that of the angular surfaces of the roller tracks, the function of which is to guide the ink rollers into gradual contact with the ink disk without striking its lower edge.

This job always gave more or less trouble on the erecting floor. Sometimes the disks were too high, and the bosses of the disk brackets had to be faced off slightly. At other times the angular surfaces of the roller tracks projected too far above the disks and had to be filed down. To get these two surfaces in correct relation, the fixture (Fig. 31) was made.

A shaft was put through the holes in the lugs *C* at the back of the bed, and the bed was placed in the fixture as shown in the lower view. Locating pins were put through holes in the feet and into the bushed holes *D* in the uprights. The ends of the shaft

were thus brought into contact with the stops at the right. Blocks *E* were placed behind the ends of the shaft and were tightened by means of jackscrews *F*. The cutter was set to a hardened block (not shown). In this position, the seats for the feet of the disk bracket were milled. For milling the angular surfaces *A* of the roller tracks, the blocks *E* were removed, and the locating pins were withdrawn from the holes in the uprights. The feet of the bed were then raised, the bed slid to the left, and the locating pins entered in the holes *H* in the uprights. The blocks *E* were put in ahead of the shaft ends, and the jackscrews were tightened, the position of the bed being as shown in the upper view.

In this position, the angular surfaces of the roller tracks were brought into the same plane occupied by the seats for the disk bracket in the first position and in correct relation thereto. While the cutter needs no horizontal adjustment, it had to be raised vertically about 4 in. To avoid both raising and lowering the cutter for each successive bed, the operations on the next bed were first to mill the angular surfaces of the roller tracks and then to place the bed in position for milling the seats for the feet of the disk bracket, as in the lower view. By thus alternating the sequence of operations it was necessary to raise or lower the cutter once only for each bed.

While the beds were heavy enough to need no clamping, as a precaution against their being lifted up under pressure of the cut, pieces *I* were attached to the tops of the end stops for the ends of the shaft to slide under. The faces of the stops and the bottoms of the slots were protected from undue wear by inserts of hardened steel.

This was designed by S. Ashton Hand while superintendent of the Chandler and Price Co. in Cleveland, O.

Fixture for Double-head Milling.—Figure 32 shows a double-head fixture for milling simultaneously both sides of a brass casting about ½ in. square of a section as shown and of five different lengths of about 9, 16, 18, 23, and 26 in. The drawing shows the work, with cut finished but in position ready to be clamped by a touch of the valve lever at the top of the fixture. This fixture is about 34½ in. long over all and has a cast-iron base for clamping to platen, with a hardened machine-steel strip for supporting the work. The work is put in from one side against the adjusta-

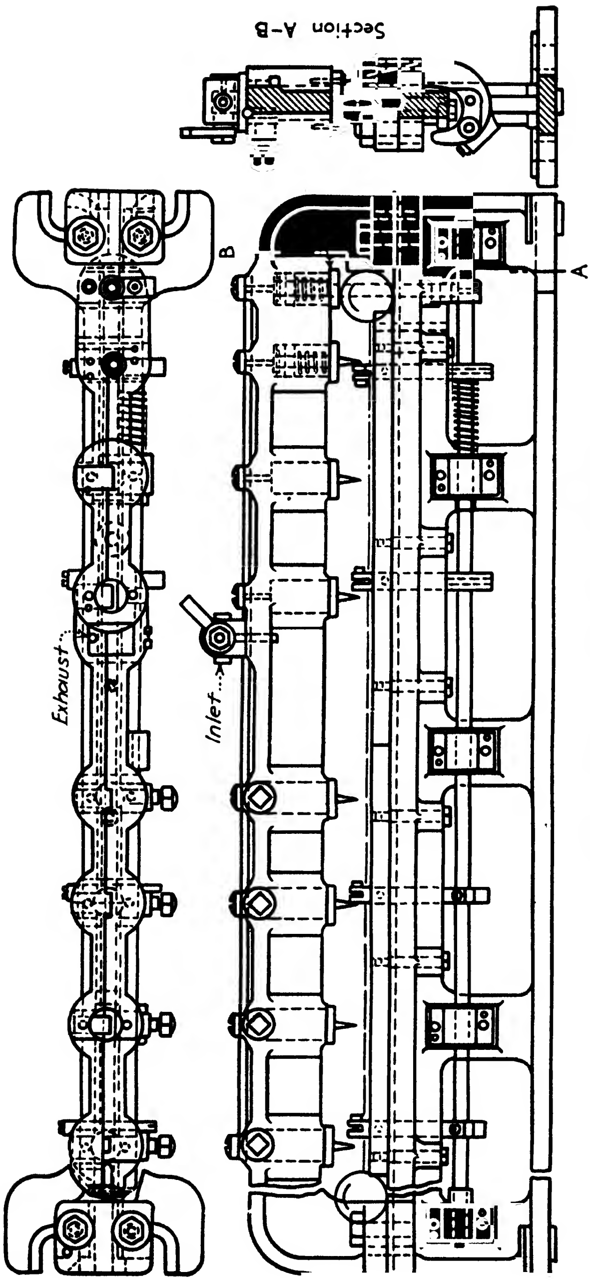


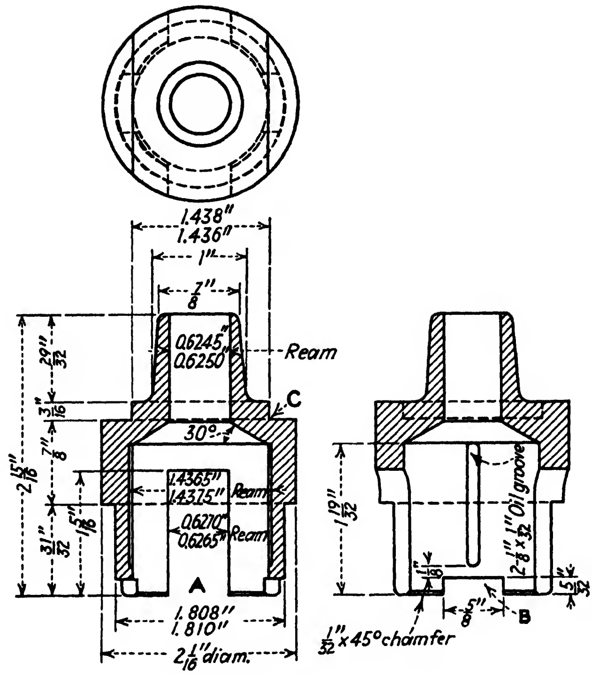
FIG. 32.—Double-head pneumatic milling fixture.

ble stop arms, which are thrown into a fixed stopped position by the torsion spring surrounding the stop-arm carrying shaft. These arms have stop pins and adjustable screw stops for different widths of work to be milled and are always in the stop position when work is ready to be put in.

Fastened with cap screws to the base casting is a cast-iron yoke which is drilled and reamed for eight 1-in. pistons, seven of these pistons having tool-steel-hardened center-punch points for clamping the work. The eighth cylinder is used to push the stopping arms out of the way of the cutters. The cutters are shown in the starting position and have a tendency to hold the work down and also against the stop pin shown.

The air enters the valve through a short piece of rubber tubing, and, when the valve is opened, the air passes to the seven clamping cylinders through a single ⅛-in. brass tube. The air also exhausts through this same tube to a by-pass in the valve in releasing. Directly above each cylinder, this air-supply tube is punctured with a small hole packed with a piece of soft rubber, and the air tube clamped at this point with the screw and plates shown. Four of these cylinders have air cutoff screws at the side to save air when doing the shorter work. A second small brass tube leads from the valve to the end cylinder operating the adjustable stop arms previously mentioned. In operation, the stop arms being in position, the piece to be milled is placed in the fixture, and the valve lever is moved. This single movement admits air, first, to all the clamping cylinders that are to be operated and, second, to the cylinder removing the stopping arms from the path of the cutter. To release the air, the valve lever must be moved back. The use of air in place of screws cuts the price of this straddle cut 50 per cent, with the same wages earned in both cases.

Four-spindle Milling Fixture.—This fixture was designed to mill the slots in the valve push-rod guide shown in Fig. 33 but can, with very little change, be made to operate on many other similar pieces, where quantity counts. As shown, this piece has two slots *A* and *B*, milled at right angles to each other and of different depths. On a six-cylinder car, 12 of these parts are used. By milling four at a time, as is done in this fixture, a lot of time is saved, and the fixture soon pays for itself.



'FIG. 33.—The piece to be milled.

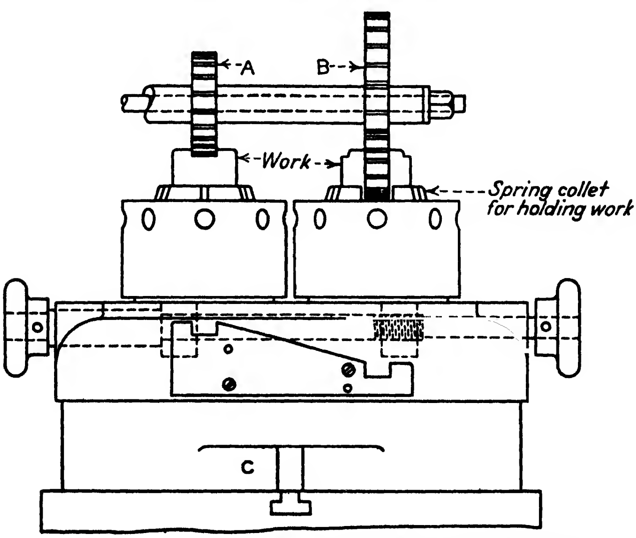


FIG. 34.—Using two sizes of cutters—with gage below.

Two cutters are used on the milling-machine arbor, as shown in Fig. 34: a small one *A* for the shallow slot, and a large one *B* for the deep slot. The cutters are spaced accurately in line with the spindles of the fixture by means of a cutter gage. Two cuts are necessary to finish the four parts. After the first cut, the fixture is revolved halfway around, the spindles at the same time automatically revolving on their own centers one-quarter of a revolution. This brings each push-rod guide in proper position for the second cut.

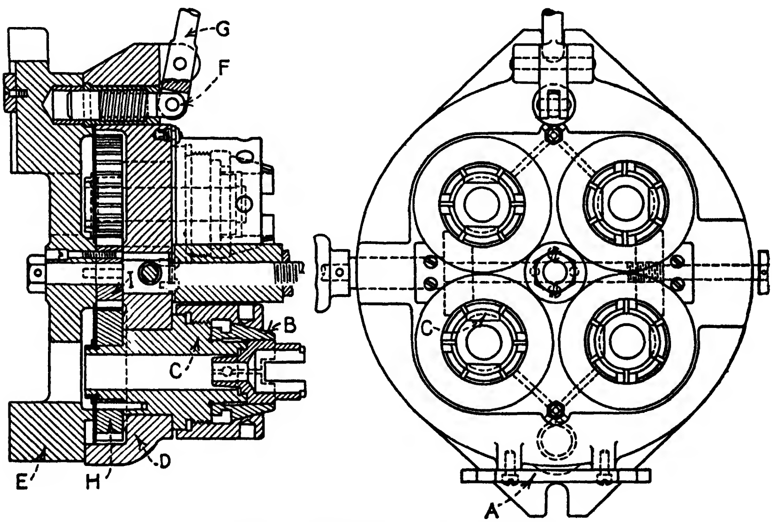


Fig. 35.—Milling four pieces at once.

The work is held in the heavy spring collets *B* (Fig. 35), which are tightened by a large spanner wrench. The parts are located in relation to the surface *C* (Fig. 33) by the slots in the vertical spindles *C* (Fig. 35). These spindles revolve in the top plate *D*, which also revolves on the base plate *E*, bolted to the platen of the miller. The top plate is locked in two positions by the indexing plug *F*, the indexing lever *G* also serving as a handle to revolve the jig. On the ends of the spindles are fastened the four gears *H*, which are in mesh with the central gear *I*, held stationary on the base plate. The ratio of the spindle gear to the central gear is two to one, so that when the top plate is revolved half of a revolution, the spindle revolves on its own center one-quarter of a revolution.

To prevent vibration during the cut, the spindles *A* are locked by the clamp blocks *B* (Fig. 36). These clamps are actuated by the clamping bolt *C*. There is a hand knob on either end of the clamping bolt, so that there is a knob in front either way the fixture may be turned. Holes are drilled through the spindles and the base plate to allow the chips to fall to the bottom of the fixture. A shield *D* prevents the chips from getting into the

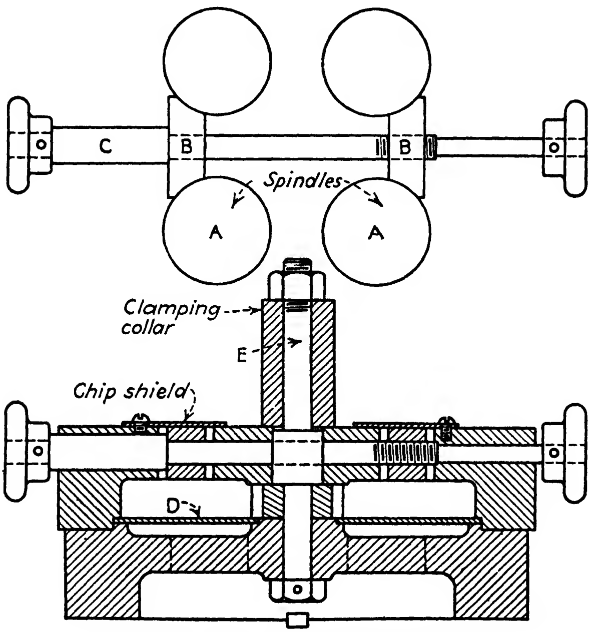


Fig. 36.—Clamping prevents vibration.

bearing. The two plates are clamped together during the cut by the bolt *E*, which has a hole drilled through it so that the bolt *C* can pass through the same center. The milling can be made almost continuous by loading two spindles while the other two are in operation.

Simple Fixture for Splitting Bearing Blocks.—The function of the fixture, Fig. 37, is to hold six bearing blocks while they are being split through the center by sawing in a milling machine.

The work, indicated by heavy dotted lines, is located in the groove *A* and is held against the steel plates *B* by the two clamps *C*. The steel plates are set in cross grooves and are held by the

pins *D*. Each of the two clamps holds one side of the blocks and prevents them from moving as the saw passes through them. The groove *F* is for clearance of the saw.

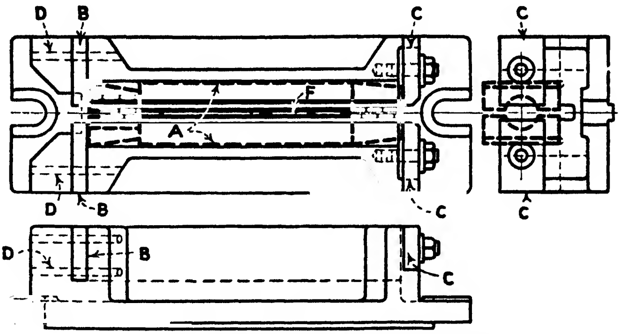


FIG. 37.—Fixture for six bearing blocks.

The fixture is inexpensive to make, and, as the six blocks are split at one pass of the saw, the long run gives the operator time to burr the blocks between loadings.

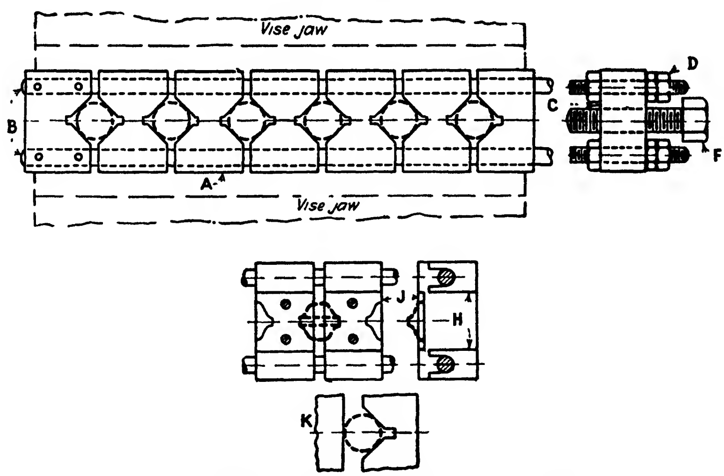


FIG. 38.—Multiple V blocks with control bolts.

A Flexible Fixture for Gang Milling.—In shops where small-lot milling is done, it is of advantage to have the tooling as flexible as is possible, so that but little time is required for changing from one job to another. For such a shop, the fixture illustrated in Fig. 38 was designed.

The fixture is held in the machine vise and consists essentially of a series of V blocks *A*, the alignment rods *B*, the yoke *C*, the adjusting nuts *D*, and the clamping screw *F*. The V blocks at the ends are single, but the intermediate ones are double. The alignment rods pass freely through the V blocks and are pinned to the one at one end. At the other end they are connected by the yoke carrying the clamping screw. To insure that the V blocks will slide apart when the clamping screw is backed off, flat springs *H* are inserted between them.

By adding to the number of V blocks, more pieces of work can be held, the number being limited only by the width of the vise

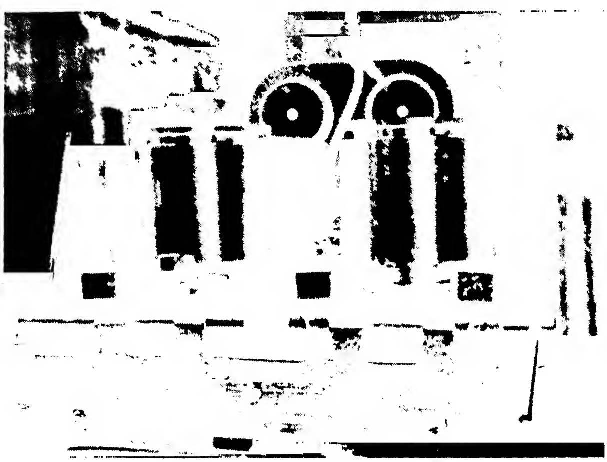


FIG. 39.—Closing fixture with barrel cams.

in which the fixture is held. For holding thin, flat pieces, nest plates can be attached to plain blocks, as at *J*. If three-point clamping is desired, blocks of the type shown at *K* can be used.

Cam-operated Fixtures.—A good example of a double cam-operated fixture is seen in Fig. 39, this being from the shop of the Kinner Airplane Engine Co. This is for milling a flat surface on one side of the cylinder flanges, two being milled at once. The cylinders are located by their bore, and the clamps swing in from the outside, over the flanges. The clamps are moved by turning the shaft in front of the fixture, the barrel cam slots in the shaft moving the clamps sideways over the cylinder flanges. One movement of the handle opens or closes both clamps on a single cylinder.

Where Straddle Mills Are Used.—In Fig. 40 is shown a double-head milling fixture for making at one operation the cut shown in section at *A* and *B*. This cut is on a brass casting and is nearly 26 in. in length, the thickness of cut being not over $\frac{5}{32}$ in. The work in these fixtures stands high, about 6 in. from the platen of the machine; the reason for this is to keep the adjustment of the cutter heads in practically the same up-and-down position for the operator, as in some of these fixtures for different cuts, the cutters must cut from underneath. The base of this

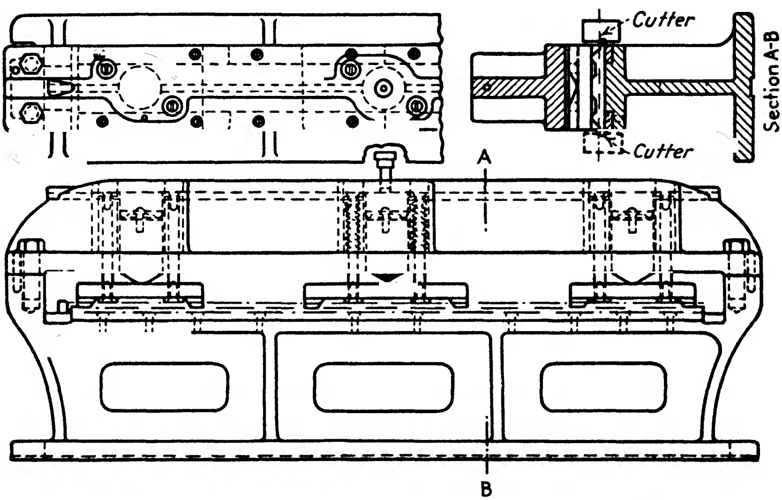


Fig. 40.—Fixtures for double-head and straddle milling.

fixture is cast iron with hardened bearing strips at the side for clamping the work on, the work being located sideways against stop pins on the border of work beneath.

The cast-iron yoke is fastened to the base by screws and pins and is bored out in three places on its underneath side for $1\frac{3}{4}$-in. pistons, which are simply cold-rolled pieces of shaft tapered on the lower end to bear against the clamping plate and having the usual cupped-leather packing held by a washer and screw at the top. At the side of each of these cylinder holes are two $\frac{3}{8}$-in. holes drilled and counterbored from the top to $\frac{3}{4}$-in. diameter, for a coiled spring, connection of spring and clamp being made by the rod with screw in each end. The valve in this fixture is placed at the connection shown in the center and has a rubber

tube connecting to an air-supply pipe. The air connection to the three cylinders is through a 1/4-in. hole drilled from each end of the yoke, with the ends of the holes plugged.

Circular-milling Attachment.—Continuous circular milling attains, as nearly as possible, maximum efficiency, and where conditions justify its adoption, highly satisfactory results can be obtained. Generally, the parts best suited to this method are such as can be grouped in an almost continuous circle and at the same time permit the use of a quickly operated locating and clamping mechanism. The output-controlling factors then become the cutter, *i.e.*, the rate of feed that it will stand up against for a reasonable length of time and the operator, *i.e.*, the facility with which the pieces can be changed. On some parts, the work can be changed so rapidly that the cutter is the final limiting element; on others, the feed must be set to allow sufficient time for the operator, although the cutter may not be working to its full capacity.

The illustration shows a fixture adapted for the 20-in. circular attachment of a Cincinnati No. 3 vertical miller for milling the base of the bracket shown. The brackets are drilled and faced before going to the miller.

Description of the Fixture.—The fixture (Fig. 41) consists of a cast-iron body *A*, 20 in. outside diameter, located on the table of the circular attachment by a central plug *B* and secured by four T-head bolts *C*. Twelve pockets are arranged round the body, equidistant at 30 deg. and radial from the center. (The enlarged sectional views show details of the pockets and holding arrangements.)

Each pocket has facings which form guides for the wedge *D*; this has two walls which clear the work when in position and which are grooved on their top faces to receive the tongue of the clamping block *E* and also have sufficient angle to give a necessary vertical movement to the block. These have also two hardened pins *F*, upon which the work rests when in position.

The wedge is operated by the T-head screw *G*, the collar of which is recessed into the wedge. The nut *H*, with which the screw engages, is recessed in the main body casting and secured by the cap screw *J*.

The inner side of each pocket has a boss, carrying the locating pin *K*, which is drawn up against its collar on the one side, and

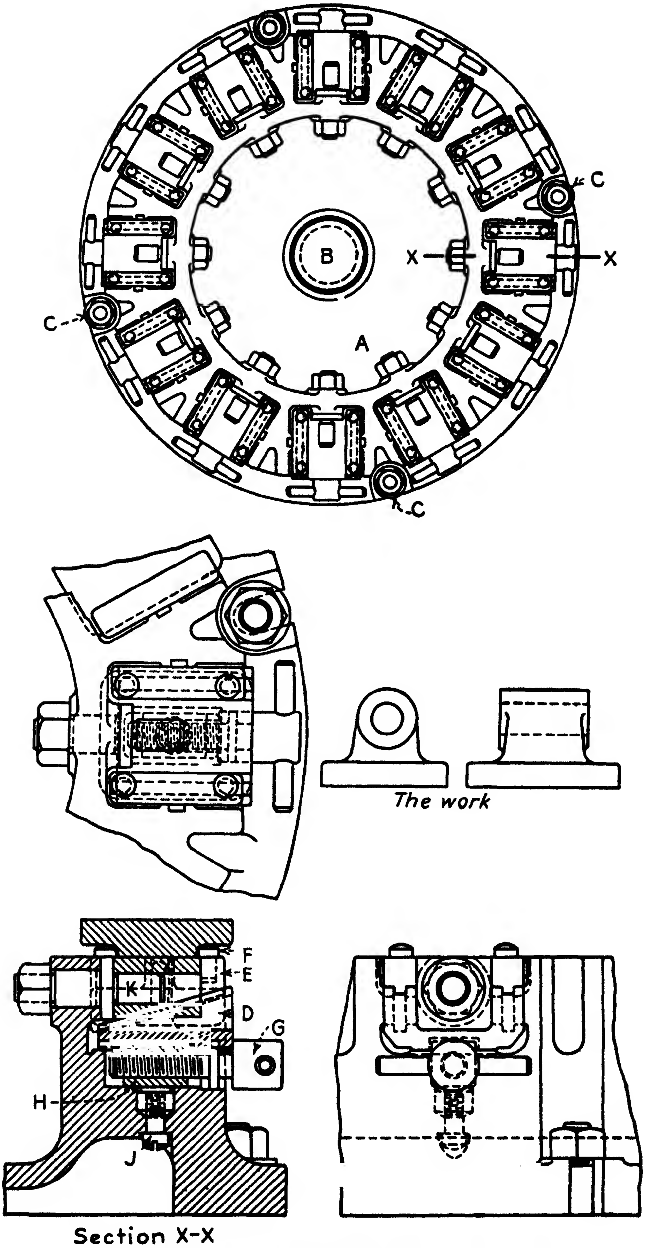


FIG. 41.—Details of circular-milling fixture.

on the other is turned a snug sliding fit for the reamed hole of the work.

The sequence of motions, therefore, is that one turn of the coarse-pitch thread tommy screw lowers the clamping blocks, the work is inserted, and the screw given one turn to the right. This forces the wedge and raises the clamping blocks which bring the work up square and tighten it on the locating pin. The work is thus supported solidly, and a milled face parallel with the center line of the hole is insured.

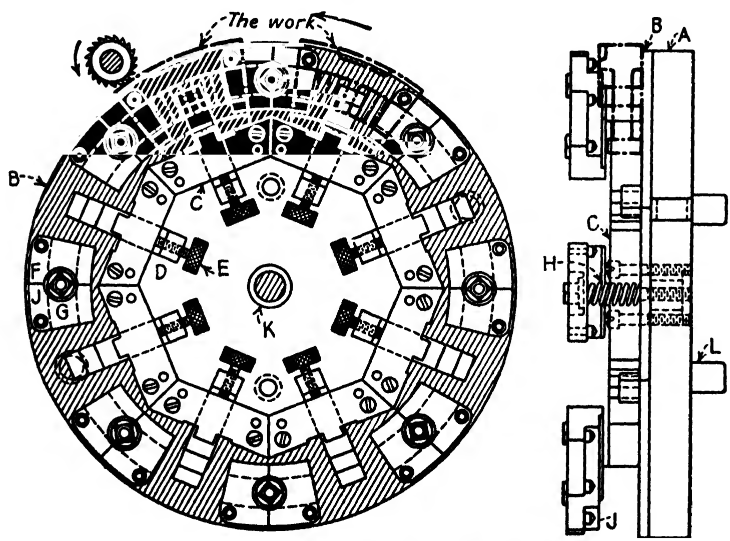


FIG. 42.—Another rotary-type fixture.

The cutter for this job is a shell end mill 4 in. in diameter, with 19 teeth carried on an arbor secured by a draw-back bolt.

A Rotary-milling Fixture.—The sketch (Fig. 42) shows a rotary-milling attachment which is designed for use in connection with a plain milling machine. It is mounted to revolve in a vertical plane so as to clear itself readily of chips and also to make use of a short-shank end mill, thus gaining the maximum rigidity that it is possible to obtain in the machine. The milling machine on which this fixture is used is equipped with a power-driven rotary table attached to a knee casting which slides on the column of the miller, and the fixture is located over a central stud and secured to the rotary table by means of two heavy cap

screws, while two steel studs in the back of the fixture serve to impart to it its rotary motion by engaging the rotary-table platen.

In Fig. 42, which shows a plan and side elevation of the fixture. *A* is a disk of cast iron machined all over and having mounted upon its front surface eight segment plates *B* of hardened tool steel, which are fastened by means of fillister screws and dowel pins from the rear of the plate and which have their front surfaces checked or roughened so as to give a good gripping effect when the work is clamped against them. The work, a sketch of which is shown in Fig. 43, is a gray-iron casting, finished on the surfaces marked *f*, and is located on its mating member by means of a tongue which enters the groove indicated at the bottom of the casting. This being the accurate point, the piece is therefore similarly located in the fixture, in order that the two parts may bear the proper relation to each other when assembled.

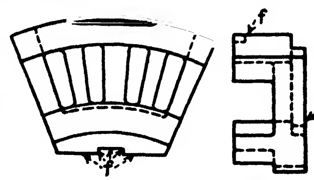


FIG. 43.—The work to be held.

Eight hardened tool-steel locating blocks are attached to the face of the fixture by means of large fillister-head screws and dowel pins, as shown at *C* (Fig. 42). An L-shaped clamp *D* slides in a slot in the block *C* and has motion imparted to it by means of the knurled-headed screw *E*, which bears against the block *C*, thus causing the outer end of the clamp to pull the work firmly against the locating block by the hook action of the clamp behind a shoulder on the piece. The roughened plates *B* are recessed sufficiently to allow the end of the sliding clamp to travel freely backward and forward, besides serving to a certain extent as guides for it as well.

The work is clamped against the roughened plates *B* by means of hardened-steel clamps *F*, which are operated by square-head cap screws *G* and pressed outwardly by the helical springs *H*. These clamps are fitted at their outer corners with two conical spurs of hardened tool steel, which imbed themselves in the work and hold it rigidly in position. This is necessary on account of the thrust exerted by the milling cutter, when irregularities in the casting are encountered, causing the cutter to take a much heavier chip than usual.

The central hole in the fixture is provided with a hardened tool-steel bushing *K*, and the fixture is fitted with two hardened tool-

steel driving studs F, which will be noticed projecting from the back in the illustration. All screws and bolts are casehardened to withstand the wear caused by repeated operation.

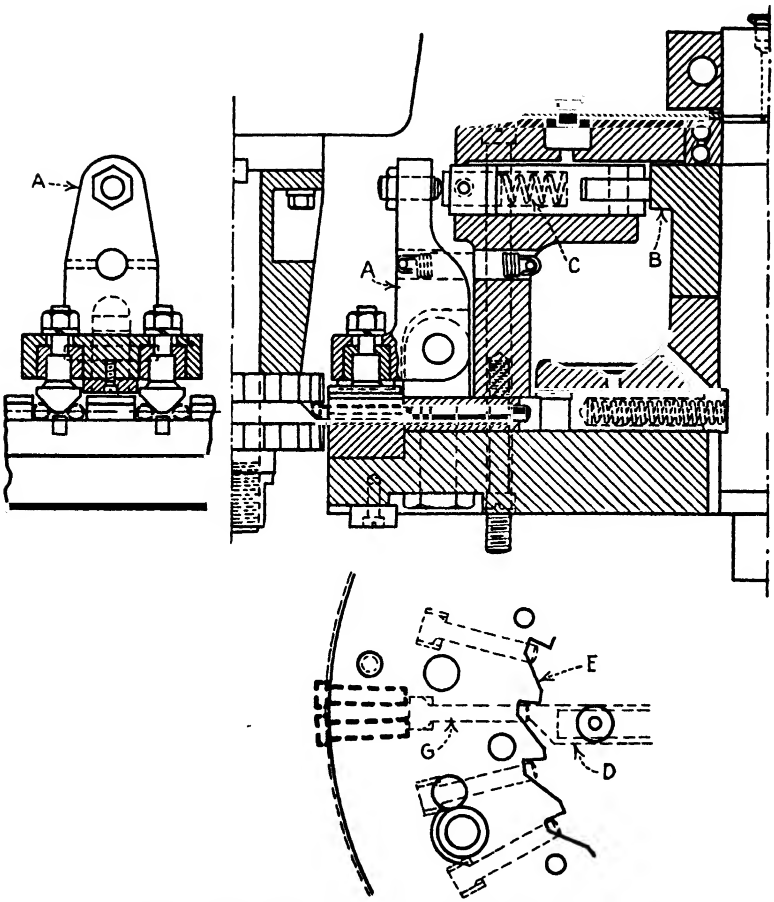


Fig. 44.—Mechanism to hold four pieces with each clamp.

The square-head screws *G* are actuated by a T-handle socket wrench, and the fixture is loaded while in continuous operation, by removing the work from the lower portion of the fixture and inserting new pieces which are easily located and clamped before they reach the cutter, thus enabling the machine to be driven at its maximum speed without any interruption of the cutting,

except during the short interval consumed when the cutter passes from the edge of one piece to the front edge of the next.

Rotary Fixture for Connecting Rod Bolts.—A fixture for milling an angular face and a flat surface on the head end of a connecting-rod bolt is illustrated in detail in Fig. 44. The fixture differs from the average form of rotary design inasmuch as the work is clamped and ejected automatically.

Loading is done at the front of the machine, four pieces being placed in each clamping section. The clamps, as shown at *A*, are hinged and have two self-aligning wedge-shaped blocks which press the body of the bolts against V-block supports. The body of the fixture, carrying the work, revolves on a stationary center plug. Mounted on the plug is the hardened cam *B*, against

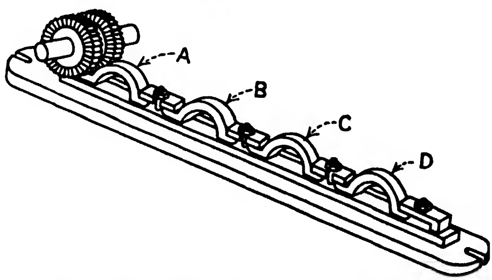


Fig. 45.—String milling of bearing caps.

which the clamping plungers bear. As the base revolves, the plungers rise and fall, engaging the heel of the clamps and causing an automatic clamping action. Provision for elasticity in the clamping mechanism is provided by stiff helical springs *C*, which are inserted in the clamping plungers as shown. A plan view of the automatic ejecting mechanism is shown below the elevation, and a front view of the holding mechanism is shown at the left. The spring plunger *D* rides on the inner face of the saw-tooth cam plate *E* so that it kicks outward when released, striking the ejector pin *G*, which has a contact face wide enough to eject two pieces at once. The arrangement of the mechanism is such that the work is ejected at the rear of the machine after the clamping pressure has been released. The machining is done in a vertical-type machine, equipped with an 18-in. rotary table. There are 12 sections, arranged to hold 48 pieces.

Continuous Milling.—A case in which continuous milling is partially secured appears in Fig. 45. The design is not ideal

but illustrates satisfactorily this style of milling. While the cutter is operating on the piece C, the piece A may be changed; when D is being machined, B may be replaced, and A clamped tightly down. The table is then lowered, run back, and raised to the correct height, and the cut started once more, and while

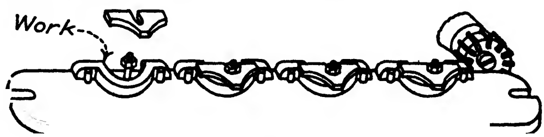


FIG. 46.—For milling the joint face.

the cutter is at work on A, the pieces C and D are put in place, and the remainder of the clamps secured.

A similar principle is illustrated in Fig. 46. In this case, however, each piece is clamped independently, and a butt mill is used. It should be noticed that, with a fixture of this kind, a machine may be run at its highest feed and cutting speed. The work is

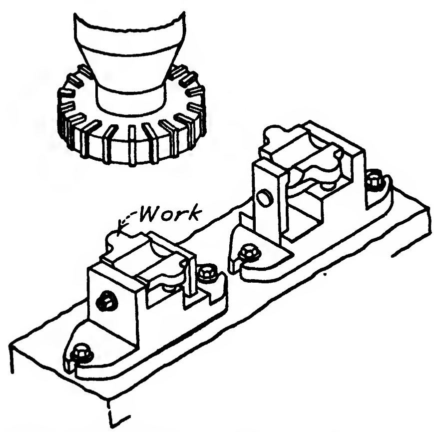


FIG. 47.—Double fixture to secure continuous milling.

right down on the bed of the machine, and the overhang of the knee and cutter is as short as it is possible to get it.

Vertical milling in many cases presents several advantages over the horizontal style, as full use may be made of the reverse, traverse, and cross-feeds without loosening that weak point in the knee-type miller, the knee joint.

A fixture, or rather two fixtures, by which continuous milling is secured, are shown in Fig. 47. The piece having been clamped

in position in the left fixture, the cutter starts to operate on it, starting from the position between the two fixtures. While this is taking place, another piece is put in the other fixture. The cutter having passed over the first piece, it is then reversed, the feed changed to a higher table travel, and the cutter passes back over the same part, taking a light skimming cut due to the piece's having been slightly sprung in the roughing operation. The feed is then dropped to its previous rate, and the roughing cut begins on the second piece; meanwhile, the first piece is changed.

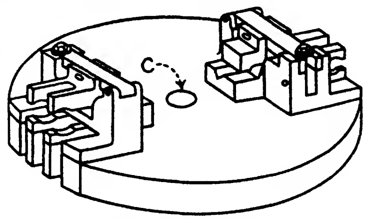


Fig. 48.—Two fixtures on rotary base.

This method could be improved upon if the table were wide enough to take four fixtures, and the cross-feed utilized. The path of the cutter would then be in the form of a rectangle instead of a straight line.

Gang milling a forked joint is accomplished in the fixture shown in Fig. 48. The clamping arrangement is duplicated on a circular base which can be located on the rotary table seen in Fig. 49. The work is at X. The central boss A serves as a register,

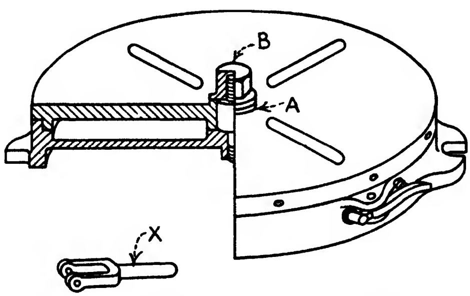


Fig. 49.—Base which carries the fixture.

and the nut B projects through the hole C. This nut is tightly secured by a box spanner which is not shown. The diameter of the table is about 14 in.

This fixture is used on a Lincoln-type miller; while the cutter is operating on one part, another piece is being secured in position. As soon as one piece is finished, the machine table is run back, the fixture swung around, the feed dropped in, and the operator

proceeds to change one piece while the machine is operating on the other.

A type of standard rotary attachment is shown in Fig. 50. It is provided with power- or hand-feed and may be used on the

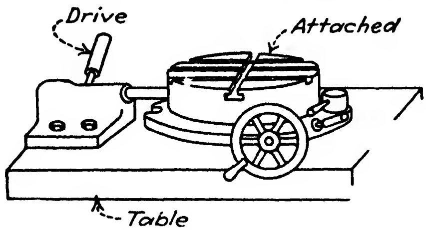


FIG. 50.—Hand or power rotary feed.

table of any kind of miller. A great variety of fixtures may be designed to go on this attachment, by which continuous work may be performed.

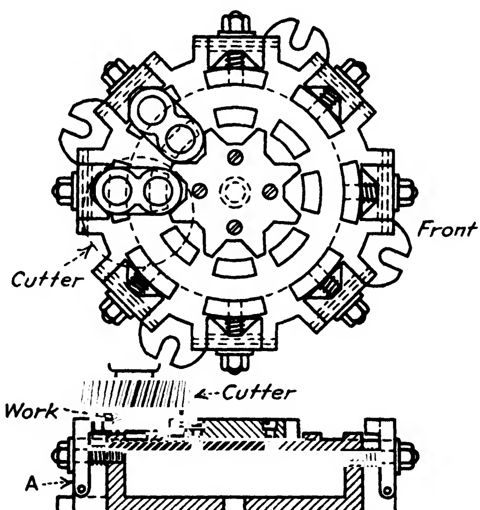


FIG. 51.—Work holder for rotary table.

A rotary fixture, such as is used on the rotary attachment shown in Fig. 50, appears in Fig. 51. When used on a vertical miller, the nearest approach possible to continuous milling is attained. In the illustration, provision is made for holding eight pieces, which are secured independently from the side. The

clamp *A* is hinged, and, when the nut is loosened, it is pushed back from contact with the work by the spring on the stud.

The work is located by the V blocks in the center; the table is partly cut away to secure a better bed for the piece. The slab cutter operates at the rear of the table and is quite clear of the

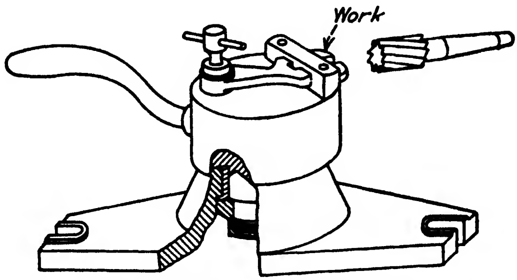


FIG. 52.—Swinging fixture for milling an arc.

operator, who has plenty of room to change the pieces as they come around to the front of the machine.

Radius and Form Milling.—Cases often occur in which it is necessary to mill an arc of large radius on a piece that cannot be handled by a form cutter or is not considered desirable to machine by that means. The fixture shown in Fig. 52 is used for milling the arc on the end of the work, which is seen clamped in position.

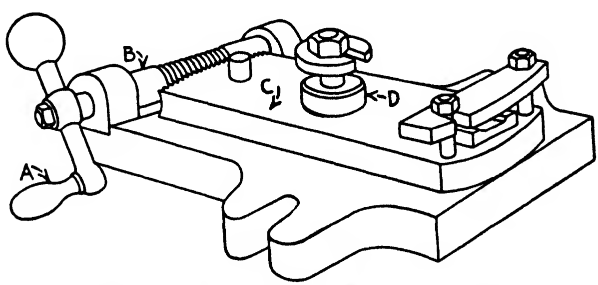


FIG. 53.—Using a screw and sector to turn fixture.

The necessary rotary motion is secured by rocking the movable portion of the fixture by hand, by means of the projecting handle. The handle should be quite long; this gives the operator sufficient leverage to resist the tendency to chatter. Small work can be handled best in this way.

The fixture in Fig. 53 performs a similar operation but provides a much more substantial means for taking a heavy cut,

although it is by no means so rapid. The rotary motion is obtained by turning the balanced handle A, operating the worm spindle B, which engages in the rear part of the plate C, rotating it about the fulcrum pin D. The plate C should be secured to the base in such a manner as to allow the movement only in the plane desired. There is a tendency to chatter if this is not provided for.

A profiling method adaptable for use on a small hand miller is illustrated in Fig. 54. The work shown is a square-ended shaft, the sides of which are milled to a radius to enable it to rock; it forms part of a flexible coupling. At H is shown a section

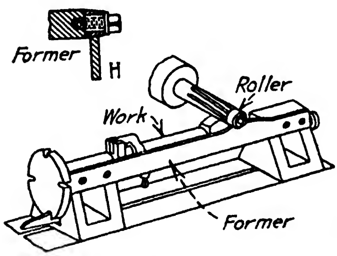


FIG. 54.

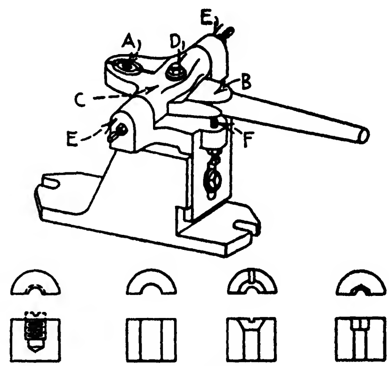


FIG. 55.

FIG. 54.—Using former for securing contour.
FIG. 55.—Quick-acting fixture for slotting screw heads.

through the roller and former, in which it can be seen that the roller is conical and that the former is at an angle to correspond to it.

By moving the table away from the machine, the cutter can be brought down farther into the work, until the required size is secured. An angle on the former of about 7 deg. gives a very convenient range of feed. The roller is made of tool steel, hardened and tempered, while the former is of machine steel casehardened. The former can easily be taken off, and others attached to the same centers of various lengths and forms to suit the part being machined.

A hand device, suitable for milling the slots in small screws at A, is shown in Fig. 55. The lever B is free to move in a horizontal direction about the point D, and the work is nipped between it and the jaw C. These two parts may be turned on the adjustable

centers *E*, and the work raised against the cutter until lever *C* comes in contact with the adjustable stop *F*, when the slot should have been cut to its required depth. The whole upper part of the fixture is capable of being adjusted for height and locked in position. The hardened bushings seen below are part of the equipment, to suit the various forms and sizes of the screws requiring to be slotted.

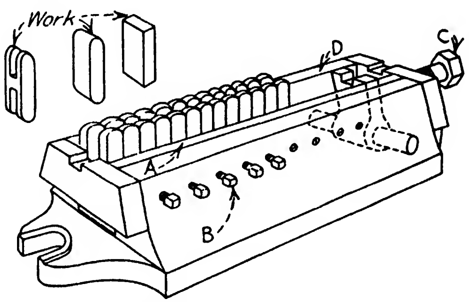


FIG. 56.—Clamping work to prevent bulging.

In Fig. 56 appears an example of the type of fixture suitable for holding a number of pieces at once, when the stock operated on may be relied upon to come uniform in size. The piece shown in the illustration is cut from rectangular, cold-rolled steel, and the variation in size does not amount to more than a few thou-

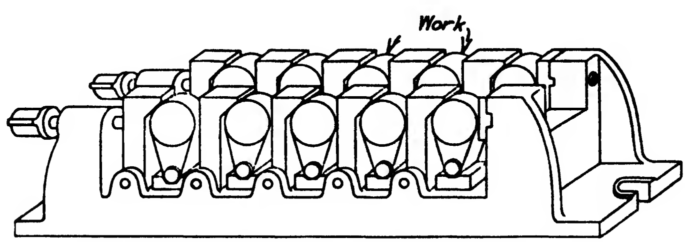


FIG. 57.—Equalizing jaws for holding rough forgings.

sandths. The strip *A*, which is supported by the adjusting screws *B*, is capable of taking care of any such slight differences.

The pieces are clamped longitudinally by the hexagon-headed clamp screw *C* pressing against the hinged plate *D*. This has the effect of forcing the work down into the fixture when tightening up. The operation of rounding the ends of the work may also be performed in the same fixture by providing an additional

packing plate to make up for the difference in the width of the part when turned in the other direction.

A fixture for holding a number of rough forgings is shown in Fig. 57. The hinged spacing blocks insure that each piece is held squarely and compensate for any difference in the size of the piece; they also hold them down into the V's around the small bosses. The double row takes full advantage of a powerful

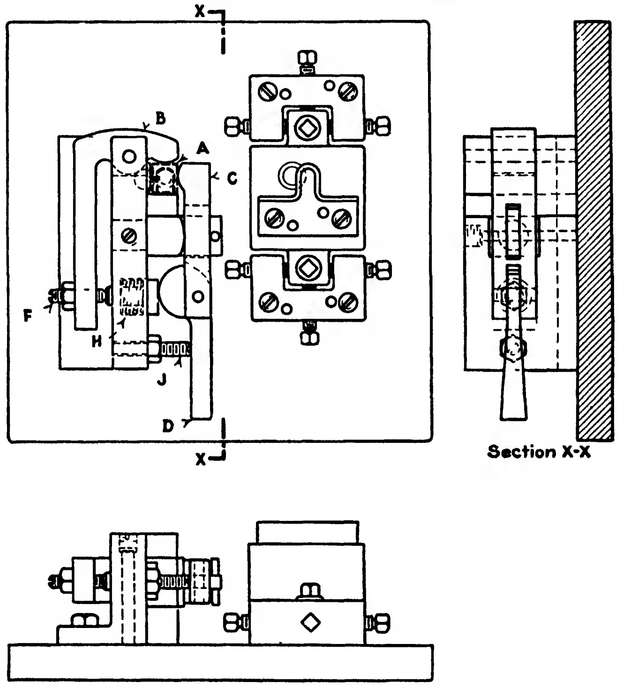


FIG. 58.—Cam lever that acts on two clamps.

machine. There is a considerable waste of table travel between pieces owing to the necessity of having a space. The advantages of using a fixture of this kind lie mainly in the fact that one man can then attend to several machines; unless this is the case, it would probably be quite as quick or even quicker to use a simpler fixture taking only one or two pieces at a time.

Quick-acting Fixture for Profiling.—In making small interchangeable parts in large quantities, especially for small-arms manufacture, it is necessary to have quick-clamping fixtures. Frederick G. Kenyon, tool designer, Springfield Arsenal, designed

the fixture shown in Fig. 58. Since clamping by screws is too slow, the fixtures are generally provided with cam-operated clamps. Such fixtures must also be self-contained, as loose pieces or wrenches lying around are likely to fall on the floor or get lost in the tool crib.

In the fixture illustrated, the work is a square piece having a tongue profiled on one end, as indicated by the heavy dotted

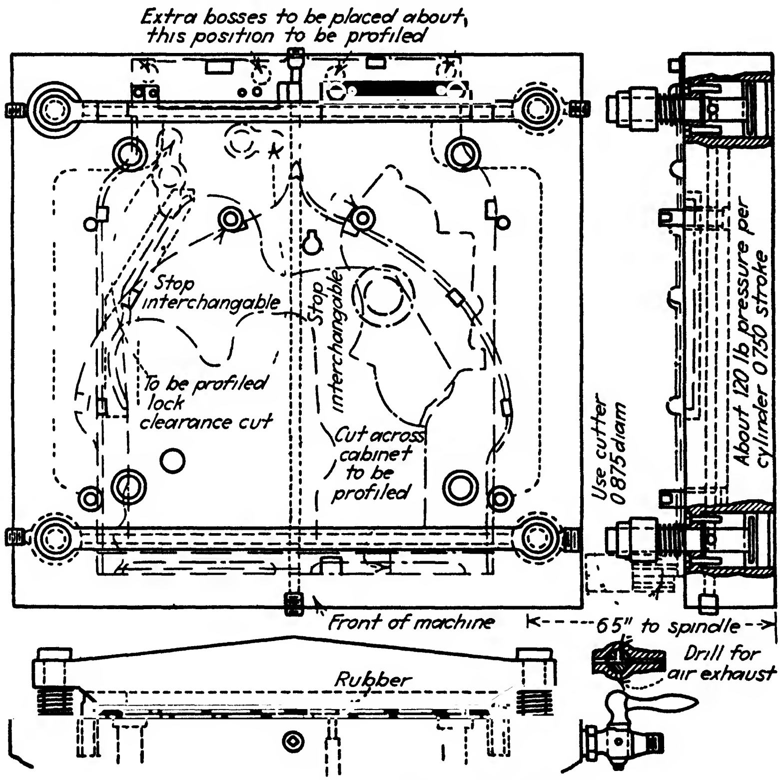


FIG. 59 —A rather complicated profiling fixture.

lines at *A*. The work is clamped in two directions by clamps *B* and *C*, both of which are operated by the cam lever *D*, which acts directly on clamp *C* and indirectly on clamp *B*. Adjustment for clamp *B* is provided by a headless setscrew and a check nut at *F*. The inner end of the screw bears against the spring-actuated plunger *H*, which helps to equalize the pressure of both clamps on the work. At *J* is a headless setscrew locked by a

lock nut which can be adjusted to prevent the cam lever from being pushed down too far.

The former, former block, and the yokes for their adjustment are shown on the same block with the plan view of the fixture, the arrangement being standard in nearly all small-arms factories.

Another Profile Fixture.—Figure 59 shows another style of profile fixture, for making some boss cuts at the back and a surface cut at the front of the fixture, as pointed out on the drawing. A right and left brass side plate is shown by the dot-

FIG. 60.—Double fixture for hydraulic-brake cylinder

and-dash line in this fixture, although in use only one side plate at a time is put in the fixture and operated on.

The base of this fixture is cast iron $2\frac{3}{8}$ in. thick, cored out to lighten, and with counterbored holes, $4\frac{5}{8}$ by $1\frac{1}{2}$ in. in diameter, for the pistons to work in. The pistons in this case work at the bottom of the open cylinder hole, the cupped-leather packing being held in place by a washer and round nut underneath forcing against the shoulder of the round steel-headed screw which connects the piston to the clamping plate. This screw, or piston rod, is automatically packed at the top of the cylinder bore by a

reverse cupped-leather packing, held in place by a metal washer and screws, as shown in section. When the air is shut off, the pistons are brought to their normal position by the two springs under each clamping plate.

The four cylinders are all connected by three ¼-in. holes drilled through the cast-iron base from side to side with a long shank drill and having the outer openings closed with a plug, as shown. The steel clamping plates are slotted at the bottom

FIG. 61.—Milling clutch plate for pressure fingers.

with a ¼-in. width of slot in which is forced a long strip of medium-hard rubber ¼ by ½ in. for clamping. This rubber is used to enable the clamp to accommodate itself to irregularities in thickness of work and is also used largely to prevent marring any surface that is stippled or where a clamp mark would show in the final finish. The valve in this case is shown in front at the right-hand side of the fixture.

Examples of Milling-machine Fixtures.—The following illustrations show some excellent examples of fixtures used on modern machines for securing increased production with stand-

ard milling machines. In Fig. 60 is a simple but substantial fixture for milling the side of hydraulic-brake cylinders. Two pieces are milled at one setting, the cylinders being positively located by the fixture and clamped by the small pilot wheel shown. Details of this pilot wheel were shown previously.

A clutch plate is being milled for the fingers in Fig. 61. The plate is drawn back against its support by air pressure and is indexed 120 deg. for the three cuts. Two milling spindles are

Fig. 62.—Use of two fixtures saves machining time

used, the upper one driving the single or slotting cutter, and the lower spindle two straddle mills which finish both sides of the lugs opposite the slot. In this way, three positions of the fixture finish all six milled cuts.

The use of two fixtures so as to avoid considerable idle time for the machine is shown in Fig. 62. Here four oil-pump drive shafts are being slotted at each operation. The husky crank handle at the top clamps all four pieces with a floating jaw and holds them solidly while they are being milled. The crank handle at the side operates a spring ejector which aids materially in speeding up the operation.

A rather unusual type of fixture is shown in Fig. 63, in which the cylinder faces, manifold, and cover faces are milled in one operation. The cylinder blocks come down the production line on conveyors and roll into the fixture. The rollers can be seen under the end gate which swings across the end of the block and is held by the latch shown. The rollers are then dropped by the lever at the side. There is a similar gate at the other

FIG. 63.—Milling three faces of cylinder blocks.

end of the fixture, and both have clamps which hold the block down during the milling operation. When the milling is done, the rolls are raised, the gates opened, and the block goes on its way to the next operation.

In Fig. 64, two special fixtures are mounted on the milling-machine table. The operator loads and unloads one fixture while the cutter is at work on the other piece. Such a combination gives almost continuous milling and keeps the machine at work with little idle time. A rough casting is loaded in the left-hand fixture, which is having the flange milled with the face or end of the cutter. The work is then transferred to the right-hand

fixture with the finished side down. In this fixture, the outside, or periphery, of the cutter is used to mill the edge of the casting. By planning work in this way and making suitable fixtures, the output of the machine can frequently be materially increased.

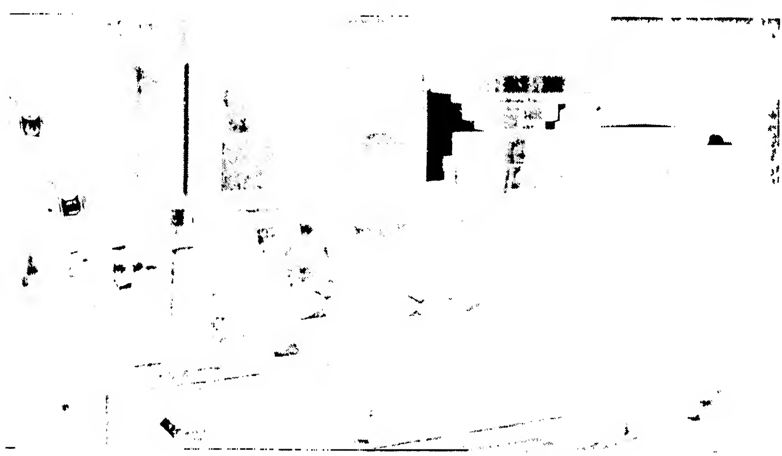


Fig. 64.—Another double-milling fixture.

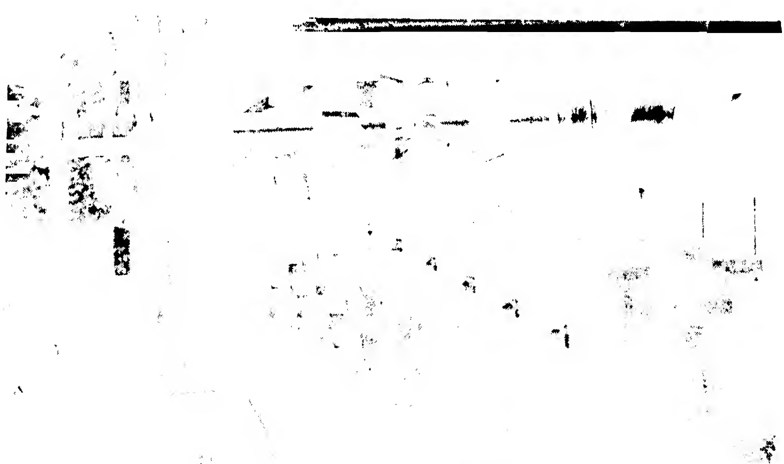


Fig. 65.—Use of jacks to support light castings against thrust of cutter.

The use of a number of jacks to support a long and rather light casting against the thrust of the milling cutters is seen in Fig. 65. These seven jacks are adjusted against the casting and then locked, before the cut starts.

A Milling Fixture.—The fixture illustrated in Fig. 66 was designed to hold the lever *A* for milling the bearing seat for a cap. One end of the lever is hooked under the block *B*, and the other is pressed downward, depressing the spring plunger *C*. The knurled-head pin in the uprights is put through a hole previously

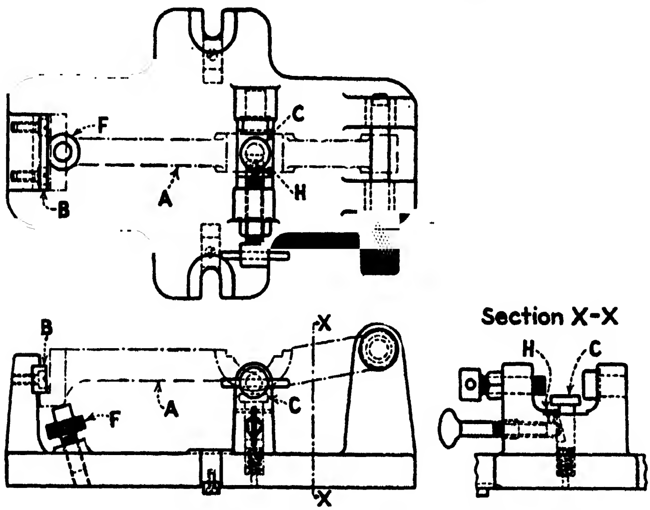


FIG. 66.—A locked spring plunger supports the work.

drilled and reamed in the short end of the lever, and the knurled-head screw *F* is brought up under the long end, holding the lever firmly in position.

A thumbscrew bearing against a wedge-shaped flat milled in its stem locks the plunger and prevents it from being forced downward under pressure of the cut. A flat milled in the stem of the plunger is engaged by the block *H* and prevents the plunger from turning, so that the wedge-shaped flat is always opposite the thumbscrew.

CHAPTER XIII

GRINDING-MACHINE FIXTURES

Fixtures for grinding-machine use form an important part of the designer's work. As with all other fixtures, accuracy and quick handling are essential.

The three fixtures shown in Figs. 67, 68, and 69 are for connecting rods for different engines. Figures 67 and 68 are well-known automobile-engine rods, and Fig. 69 is the master rod

FIG. 67.—Fixture for face-grinding Ford connecting rod.

for a radial airplane engine. Figure 67 is the first operation on the side of the rod in which it is necessary to have the sides of the rod square with the bore. As will be seen, the rod is carefully located from the bore and supported sideways by the stop screws shown. With the first side ground square, it is necessary to clamp the rod only on the first face ground and prevent its turning on the table of the grinding machine. This can be a much simpler fixture than the other, as in Fig. 70.

The other automobile fixture shows the grinding of the large bore. The correct center distance is secured by locating the

small end of the rod over a pin which is properly located. The large end is clamped by quick-acting jaws which hold the large end in place during the grinding operation.

FIG. 68.—Fixture for bore of Chrysler connecting rod

The small holes for the pins that carry the articulated rods in the radial airplane engine (Fig. 69) are being ground on a planetary grinder in which the wheel travels around the circumference of the hole. The rod is carefully located on the plate, which can be moved in both horizontal and vertical directions to bring the different holes in line with the grinding spindle. This is used in the shop of one of the well-known aviation motor builders.

FIG 69 —Fixture for airplane-engine connecting rod.

Fixtures for Crankshafts, Gears, and Valves.—Fixtures for use on grinding machines now form an important part of the designer's job, and it seems well to illustrate a few that have been

successful in production work in large plants Those shown in Figs. 71 to 75 are from designs of the Landis Tool Co. for use on their grinding machines.

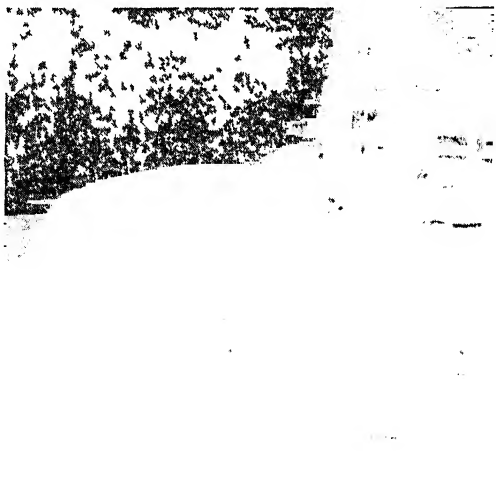


Fig 70 —Simple fixture for connecting rod

Fig 71 —Grinding fixture for small compressor crankpin

Figure 71 is a close-up of a fixture for grinding the compressor crankpins of a well-known household refrigerator The shaft is located radially by means of an arm fastened to the left crank

fixture. Lengthwise location is secured against the left-hand fixture block. There is a notched plate at the rear of each carrying block which is controlled by plungers which enable the operator to move the crank forward or back to line up for a new shaft. There is also an arm that prevents the operator from starting the work rotating before it is clamped in the fixtures. The work support is shown in position against the crankpin being ground.

Fig. 72.—Bevel gear in grinding fixture.

Figures 72 and 73 show a fixture for holding bevel gears that is somewhat unusual in design. The bevel gear is centered by rolls at the pitch line, the rolls being held by the springs shown. The gears are held in the chuck by a hydraulically operated draw or pull rod which carries two clamps which are pivoted near the

Fig. 73.—This shows rolls for locating gear teeth and clamp for holding.

front end. This permits them to close when the gear is pushed on the rod and open so as to clamp the gear when the rod is drawn back. The wheel slide is set at an angle of 45 deg., and

the face of the wheel beveled by a truing fixture to form a 90-deg. angle. This allows the grinding of both the hub and the back of the gear at the same setting.

FIG. 74.—Fixture for grinding valve faces.

For grinding automobile-engine valve faces, the fixture in Fig. 74 was designed. The face of the valve is located against a semicircular tool-steel shoe. Two small shoes at right angles

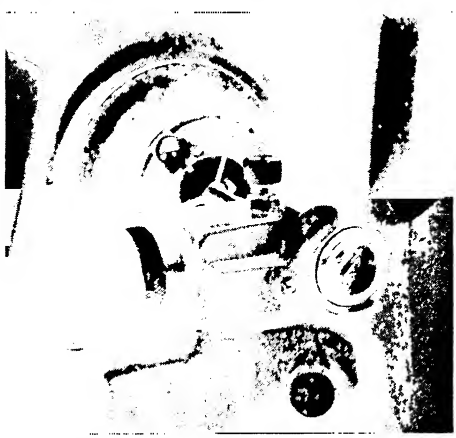


FIG. 75.—Valve in place in fixture.

support the stem of the valve against spring. The end of the stem is held in a collet chuck, which also carries a spring-loaded ejector which pushes the ground valve into the operator's hand

when the collet is released. A small metal trough helps to guide the valve stem into the collet in loading. The collet is hydraulically operated. Figure 75 shows the valve in place.

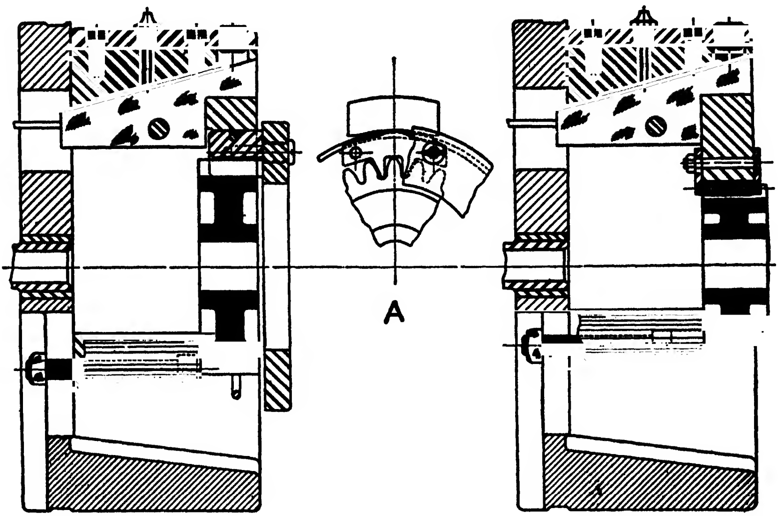


FIG. 76. FIG. 77.

FIGS. 76–77.—Heald chucks for grinding bores of gears.

Gear-grinding Fixtures.—Holding gears for finish-grinding the bore concentric with the teeth requires special fixtures. It is general practice to hold gears by the pitch line of the teeth, usings roller of proper diameter for this purpose. Special chucking fixtures for this work are made from patented designs, while builders of grinding machines also supply these with the machines when ordered. These are made by the Heald Machine Co.

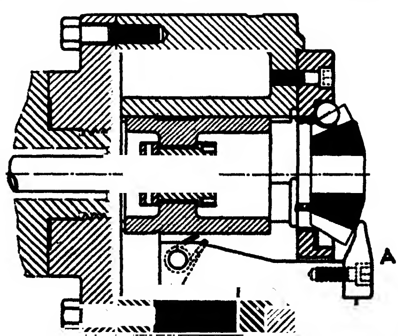


FIG. 78.—Heald chuck for bevel pinion.

Two chucking fixtures for spur gears and two for bevel gears are shown herewith. Figure 76, however, holds the gear by using three two-point rockers which bear on the root diameter. A detail of this rocker and its bearing is seen at *A*. In Fig. 77, the holding jaws carry

rolls loosely in a cage which is closed on the gear by the wedge angle on the jaw.

Bevel-gear fixtures are seen in Figs. 78 and 79. The first locates the gear by balls which bear on the pitch line, as seen

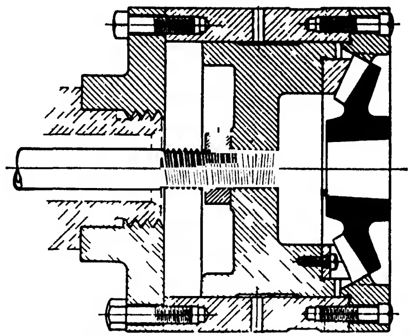


FIG. 79 —Another type of Heald chuck for bevel gears

These balls are held in spring retainers. Three jaws, as at A, hold the gear in place Another type of fixture is shown in Fig 79, where the bevel gear is held against the face of the teeth

FIG. 80 —Landis magazine fixture for grinding camshaft flanges.

and clamped by a ring at the back. This ring has openings so that the gear can be pushed through it and then turned half the width of a tooth.

In Fig. 80 is a rather elaborate hydraulic fixture for polish-grinding the inside face of the camshaft flanges. The wheel head is set at 45 deg., as in Fig. 73, and the wheel dressed by two

FIG. 81.—Close-up of cam-grinding fixture.

diamonds built into the wheel guard and operated hydraulically. The magazine, or horizontal turret, carries the camshafts into grinding position and away from it by hydraulic mechanism which is controlled by the operator through a foot pedal. Small locating rollers are attached to the hub of the fixture at the right and hold the flange against the driving mechanism as it revolves. After the grinding operation is finished, the camshaft is released as the turret indexes, and the finished shaft rolls down the track shown under the fixture. A detail of this fixture is seen in Fig. 81.

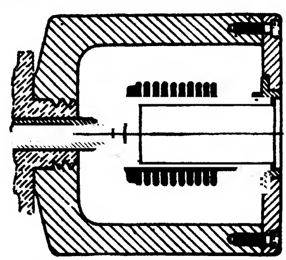


FIG. 82.—Heald fixture for closed-end cylinder.

Fixture for Closed-end Cylinder.—For grinding cylinders such as those used in some designs of airplane engines and

engines for smaller work, the balloon type of fixture (Fig. 82) is frequently used. This locates the cylinder by a finished hole

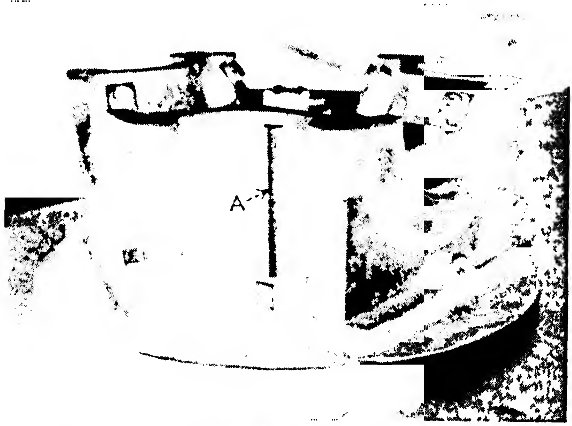


FIG. 83.—Self-aligning fixture for grinding face.

at the closed end and the finished outside of the open end. The locating plates at the outer end can be made with quick-acting fastenings instead of the screws shown.

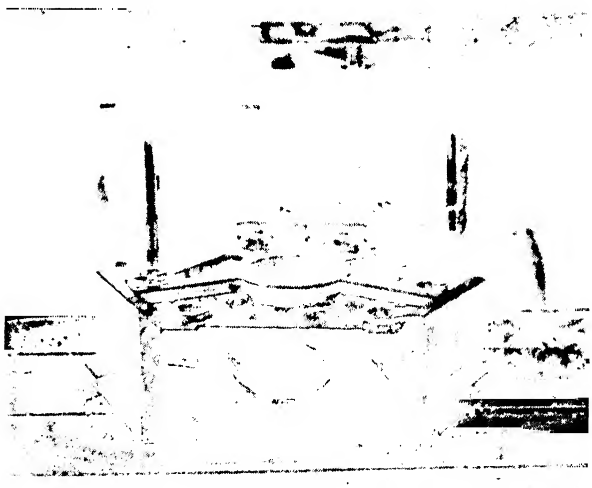


FIG. 84.—Fixture for drilling the same hub.

These fixtures can be made with two arms instead of a closed cylinder, so that the work can be mounted and removed much

more easily. In such cases, the revolving fixture should be properly guarded.

Two Propeller-hub Fixtures.—A simple but effective fixture for face-grinding the mating joint of half a propeller hub is seen in Fig. 83. Each jaw is self-aligning to compensate for any inequality in the hubs, and a central plate holds the forging in place by means of a central bolt and nut. The gage post *A* is

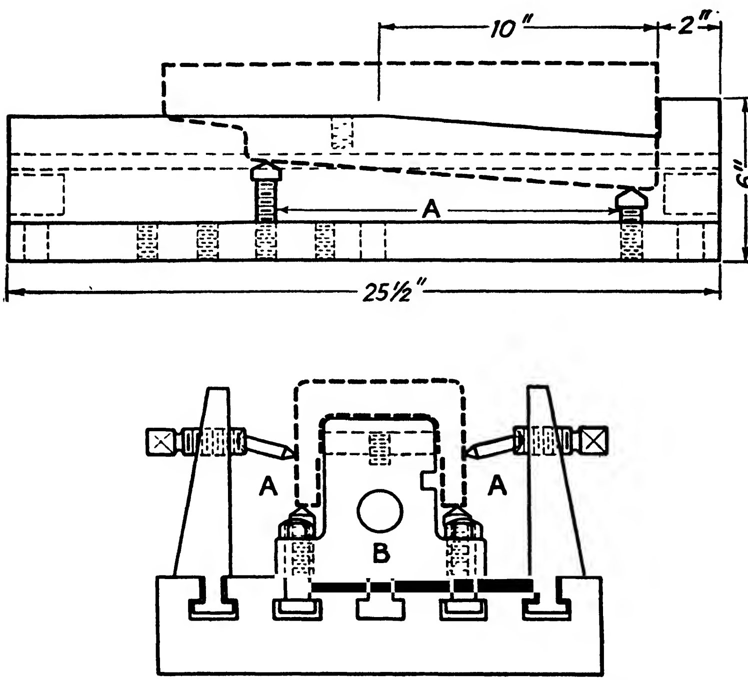


FIG. 85.—Fixture for grinding driving box wedges.

for setting a surface gage so that the hub may be quickly leveled to insure the removal of an equal amount at all points.

Using the ground face for insuring squareness of the holes, the hub is forced up against the underside of the drill jig, as in Fig. 84. The hub is put in place with the jig upside down, which permits the accurate locating of the hub in place. It is held by wedges shown in two of the supports. The holes are both drilled and reamed in this jig.

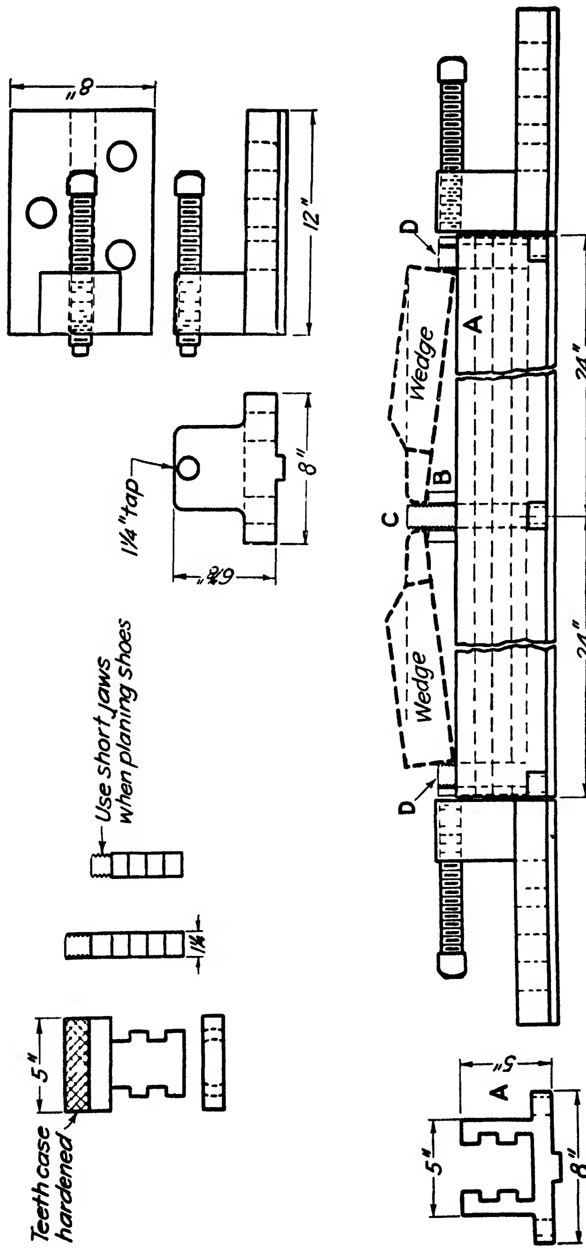


FIG. 86.—Grinding two wedges at one setting.

RAILROAD SHOP FIXTURES FOR SHOES AND WEDGES

Planing still predominates as a method of machining shoes and wedges for locomotives, although milling machines are being used in some of the larger shops. In either case, fixtures or special chucks are used to hold the work. Where the shoes and wedges are machined in strings, as on either a planer or a planer-type miller, the fixtures are similar. If, however, a miller of the manufacturing type is used, it is customary to use air-clamping fixtures which, while holding but one or two pieces, enable them to be handled rapidly.

Two types of planing fixtures are shown: Fig. 85, for planing the outer, or flat side of the wedge, and Fig. 86 for the inner or channel side. In Fig. 85 the edges are supported on four cone-pointed screws that can be adjusted for height to suit different work. Double-pointed, cone-end pins hold the work from each side, as at *A*. Uprights which carry hollow-head setscrews can be set at desired points and force the hardened pins into the work. Central supports, such as at *B*, make it easy to center the work and to take care of end thrust by suitable clamps.

A somewhat different chuck, for planing the inside of wedge, is seen in Fig. 86. Here the work rests on top of the body *A*, the taper being secured by blocks as at *B*. Clamping is done by the serrated jaws with hardened teeth as at *C* and *D*. These jaws slide in double T-slot guides shown in the end view. The end jaws are forced against the work by 1¼-in. screws, holding two pieces at once against the long jaw in the center. When shoes are being planed, only the short jaws are used.

These chucks have been found useful by one large railroad, and were designed primarily for use on a crank planer. They could also be used for milling on almost any type of machine.

Section 5

HANDLING LARGE SUBASSEMBLIES

CHAPTER XIV

WELDING AND ASSEMBLING FIXTURES

This section differs materially from the earlier portions of this volume in that, instead of showing the ordinary types of jigs and fixtures used in machining processes, it enters the field of welding and assembling of larger parts. The demand for aircraft during the war emergency necessitated the adoption of mass-production methods in the airplane plants which had formerly built, instead of manufactured, their product. This was entirely logical owing to the small quantities formerly ordered and the necessity for frequent changes. Although some changes are always necessary to meet new conditions, there are many parts of modern airplanes that can be standardized sufficiently to warrant the use of large fixtures, such as some of those illustrated herewith. Some of these combine drilling and other machining operations with assembly, which includes the riveting of sub-assemblies into a whole fuselage or into a wing section.

Some of the wing-assembling fixtures are so large as to astonish those who do not realize the huge size of modern military and commercial planes. One noticeable feature of many of these fixtures is the extensive use of large pipes or tubing in their construction. These tubular designs make it possible to secure large holding structures which are stiff enough to prevent undue deflection and which are at the same time lighter than might be thought possible. An exception to this is shown in the bridge type of construction design used by the Canadians in building the huge Lancaster bombers. Both arc and torch welding have been of great help in producing many of these fixtures in a form of construction that is economical in both time and material.

ASSEMBLY-FIXTURE CONSTRUCTION

In order to have the large fixtures that are used in airplane work give satisfactory service, it is necessary to have them designed to resist deflection when in use. Some of these fixtures are very large, as will be seen, and stiffness is most important. The Lockheed Aircraft Corporation, well-known builders of large

planes, emphasizes deflection above everything else. They put the various factors of fixtures in this order: rigidity, stability, accessibility, economy, and appeal to the workers and to subcontracting firms. For this reason they pay more attention to the symmetry and appearance than might be supposed.

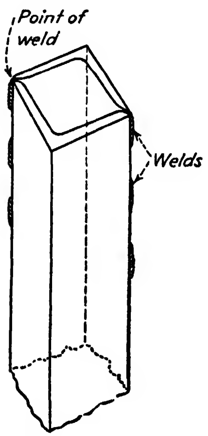


FIG. 1.—Box column made by welding two angles.

About six years ago the engineering department undertook an investigation of the types of fixtures then in use to see what improvements could be made. Up to that time their fixtures were made of welded tubular sections which were bolted rigidly to the floor. As standard sections were used, many of the members were too large, while others, being too small, failed to add rigidity to the fixture.

The engineering department developed and built special testing machines so that structural sections might be examined for various characteristics. As a result they finally decided that a box section, built up of welded angle irons, was the most rigid form for these fixtures. These fixtures vary from a single beam to a three-dimensional beam construction 25 ft. long. These are to be used in assembling the new C-69 plane, which is known as the Constellation.

As shown in the illustrations, these are built up from angles welded into a hollow square. In Fig. 1 two angles form a simple box section. The welds need not be continuous. They are from 4 to 6 in. long with equal unwelded spaces between the welds.

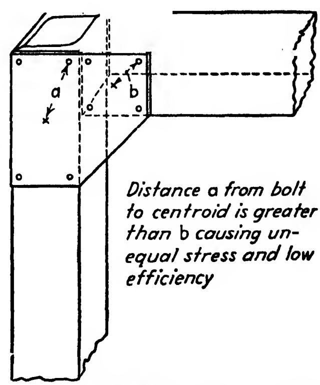


FIG. 2.—Right-angle joint that is not strong enough.

Connection between Members.—A great deal of attention has been given to the type of connection between members. It was found that from the standpoint of deflection the ordinary gusset set at 45 deg. (Fig. 2) gave about 5 per cent, and that con-

sequently the deflection was excessive. The gusset finally settled on is shown in Fig. 3. This gives an equal distance from the centroid to the bolts and dowels in both the vertical and horizontal members, and 95 per cent efficiency is claimed for this joint. In one case, a fixture 405 in. long with a calculated deflection of 0.008 in. under a load of 200 lb. showed an actual deflection of 0.007 in. in its length. This lies well within the required degree of accuracy.

In the original design the usual stress-analysis method is used for determining the structural strength of the fixtures at the various joints. The technique involved for the high degree of perfection required is developed in order to obtain absolute rigidity with minimum deflection. From two to four dowels are used in each member, and these dowels are a driving fit into the gussets. Naturally, extreme accuracy is required. Hardened-steel bolts are used, and the holes in the gussets are reamed to make an absolute fit between the gusset and the bolts. It is claimed that the dowels provide the larger part of the rigidity, the function of the bolts being largely to hold the gusset to the member and prevent sidewise deflection. However, no definite or positive statement has been made to this effect, and it is not stated positively that the experiments have been carried far enough to consider this an authentic statement.

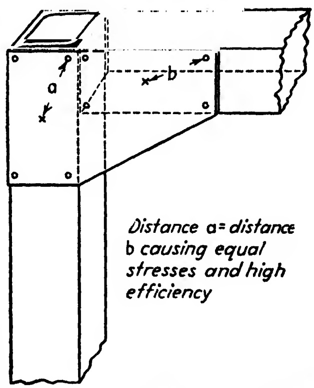


FIG. 3.—These proportions make an efficient joint.

One advantage claimed for this type of fixture construction is that there is always a large area of contact between any fixture that may be applied to the fixture members and that dowel and bolted fixtures can be used. If for any reason a change in the position of a fixture is necessary owing to a change in the design of the part, it is only necessary to drill for the dowels and bolts and, of course, to tap the new bolt holes. In other constructions, welding has been resorted to as a means of rapid production so that once the fixture is constructed no alterations can be made without much cutting and rewelding.

It has also been found that the box-type fixture is frequently 95 per cent salvageable when changes are necessary, whereas with the welded shell or tubular sections there is very little salvage if any. The box-section fixtures are generally supported from the floor by these columns, giving a three-point suspension. These columns are not bolted to the floor, and consequently the true alignment of the fixture is not altered by floor disturbances. The columns extend to the highest possible point in the fixture instead of to the base, which helps to eliminate distortion.

It is claimed that fixtures can be attached to the welded box section without disturbing the equilibrium of that section to any extent. However, fixtures welded to tubular or shell sections move the centroid from the position of the center of gravity of the shell to a proportional distance from that point, with the result that stresses that produce deflection are set up in the member. Fixtures attached to the box section will, of course, do the same thing to a certain extent, but the result is minimized, owing to the greater rigidity of the box section.

MATING OR LOCATING JIG FOR BOMBER WINGS

The bridgelike structure shown in Fig. 4 is known as a "mating jig" and is used in assembling the big B-24 bombers in the plant of the Consolidated Aircraft Corporation. The wing is first mounted on a carriage from which it is picked up by a sling on the traveling crane and lowered on four supporting posts. These posts are adjustable vertically by means of elevating screws used to level the wing section.

The mating jig (Fig. 4) is then lifted by the crane, using the top ring as shown, and placed over the wing section. This jig locates the wing and fuselage, or body, in their correct relative positions. The illustration shows the bridge construction of steel tubing, which (unlike most jigs) is strong enough to be independent of any foundation.

LARGE FIXTURES USED IN AIR-FRAME WORK

Some idea of the size to which air-frame-assembly fixtures have grown may be had from a few examples from the Nashville Division of Vultee Aircraft, Inc., shown in *Wings* by J. M. Durliner, chief of methods and control, of that plant.

FIG. 4.—This is called a "mating" jig as it locates, or mates, the wings and fuselage in correct relation.

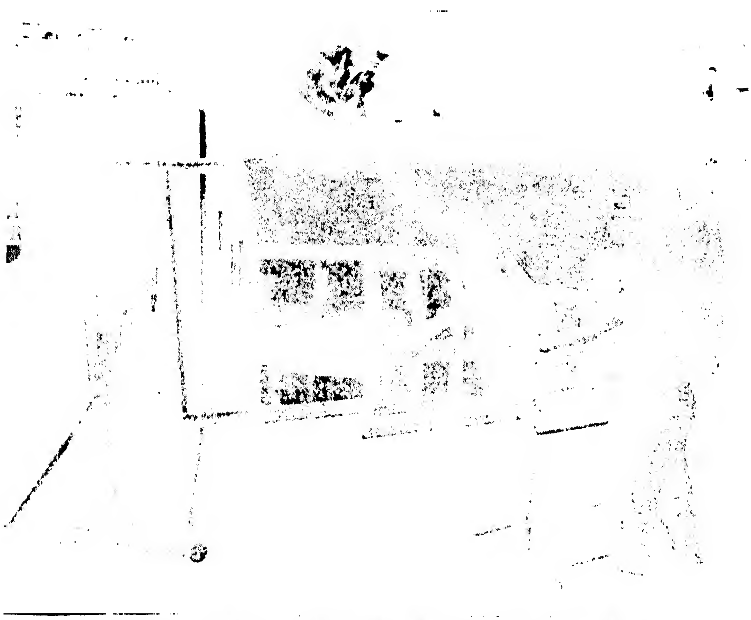


FIG. 5.—This holds the forward section of a Vultee plane.

In Fig 5 may be seen the fixture that holds the completed forward section. This fixture, or stand, is on wheels and can be moved where it is wanted. The section can be rotated at will. The man on the floor is checking the wing-fairing attachments,

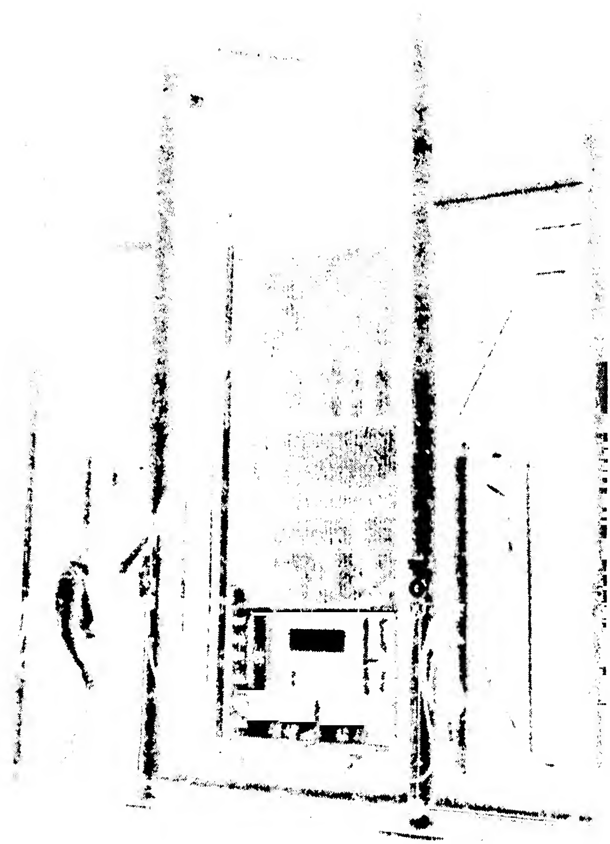


Fig. 6.—One of the large fixtures used at Vultee.

using what is known as an "apply" fixture against the side of the section. The "apply" fixture is also on wheels.

Figures 6 and 7 give an idea of the size necessary in some of the fixtures. These are built of large steel tubing as is common, but not universal, in the industry. Air outlets are provided at the sides for tools, and portable scaffolds with steps are available when needed.

When the section shown in Fig. 5 has been approved, it goes to the motorized conveyor. Here all possible parts are added before it is mated with the rear section. The carrier provides adjustment and rotation, also devices for clamping quickly in any

FIG. 7.—One of the large "roll-over" fixtures used in the same plant.

desired position. It is of interest to note the flexible supporting wires that hold it to the overhead trolley.

Two other views of large fixtures are seen in Figs. 8 and 9. In Fig. 8 the assembled skin panels are slid over the bulkheads and are secured by the drilling jig. Drill cages are lowered over the assembly and the joining holes are drilled. Only locating

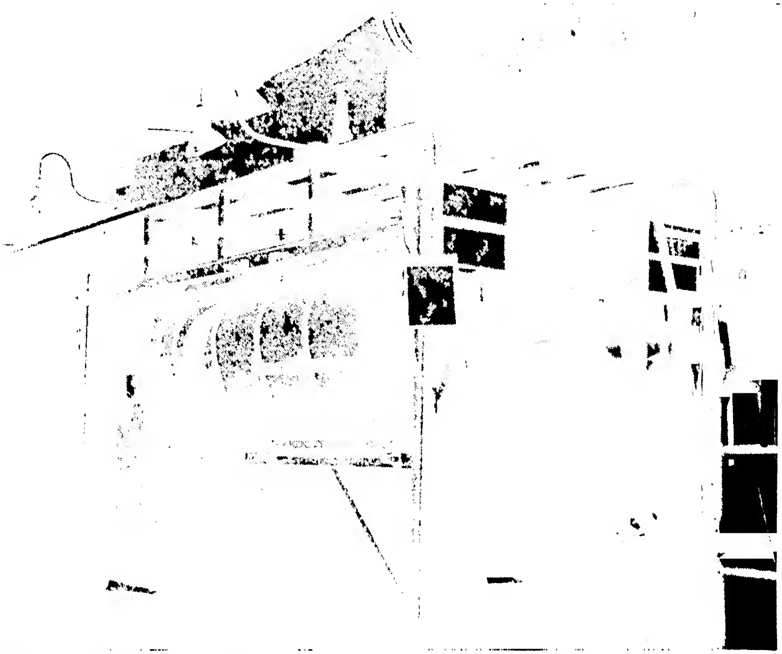


FIG 8 —Here women assemble the skin panels These fixtures are built for convenience of working position

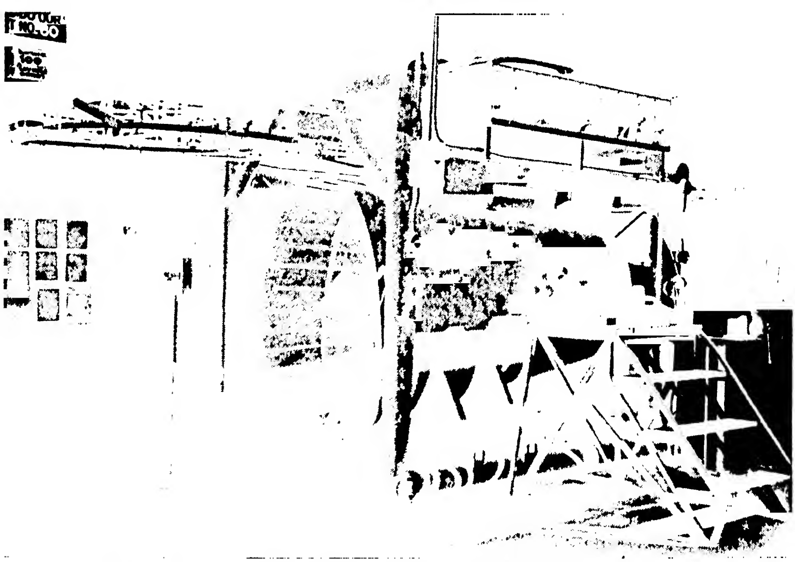


FIG. 9.—This fixture is used in mating the two halves of this monocoque assembly.

rivets are driven. Cleco fasteners hold the assembly together so it may be removed to the proper stands. Instruction cards and assembly schedules are attached to each fixture. Special lighting, quick-acting clamps, and comfortable working positions are provided. Both the operators in Fig. 8 are women.

The fixture in Fig. 9 is for making the two halves of this monocoque assembly. The lower half is held by a permanent form at the bottom. The upper half is located by a plate at the rear and a counterbalanced locating ring at the front.

This shows the corner-leveling screws, the lighting fixture, the substantial step ladder and platform, and the convenient storage of small parts over the upper member.

JIGS AND FIXTURES FOR THE THUNDERBOLT

Other interesting examples of jigs and fixtures used in building warplanes are found in the plant of the Republic Aviation Corporation, where the Thunderbolt fighters are made. The first of these is a form of drill guide which is common in all plane plants in drilling aluminum sheets and which does away with a lot of drill bushings. As seen in Fig. 10, the drill spindle carries a guide with a coned end. This end fits into a similarly coned hole in the jig templet that is clamped to sheets to be drilled. The coned guide is spring-mounted and finds its way into the hole in the templet before the drill starts to cut. This makes a very economical method of securing jig-drilled holes without the cost of a jig with large numbers of hardened bushings.

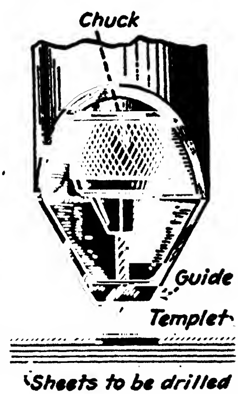


FIG. 10.—Drill guide that locates the drill by larger holes in the templet.

All fixtures used here for subassemblies are built and maintained by expert toolmakers. Figure 11 gives an example of this and shows how the bulkheads in the tail section are held while the predrilled stringers are connected to them. It will be noted that leveling bolts are provided in the base plate of the fixture so that alignment can be secured and maintained.

The fixture for the center panel (Fig. 12) has locating points for the main center spar and for the leading and trailing edges.

The fore-and-aft ribs are then riveted to the spars and to the leading and trailing edges. Each section locates itself by accurately spaced holes drilled during subassembly in special jigs designed for that purpose. All necessary stiffeners, brackets,

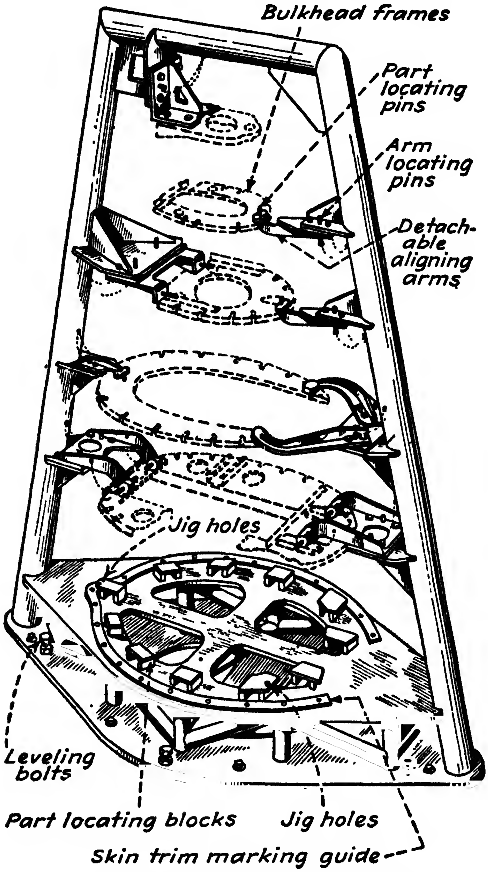


FIG. 11.—A fixture that holds the different bulkheads while the stringers are connected to them.

and accessories are added before the skin is applied. This avoids the necessity of working in a restricted space.

Each fixture for the outer panels of the Lancer, known as P-43, is designed for the assembly of one left- and one right-hand panel as seen in Fig. 12. As will be seen, the wing assumes considerable taper and the fixture conforms to this shape.

Toolmakers use reference sketches, such as Fig. 12, to build these fixtures. All dimensions are taken from drawings of the plane parts. Sketches of this kind are prepared for every major plane part.

BULKHEAD ASSEMBLIES

Another interesting assembling fixture is shown in Fig. 13. This is made up of steel tubing and has a central, or ring, section that permits the work to be turned to any desired position.

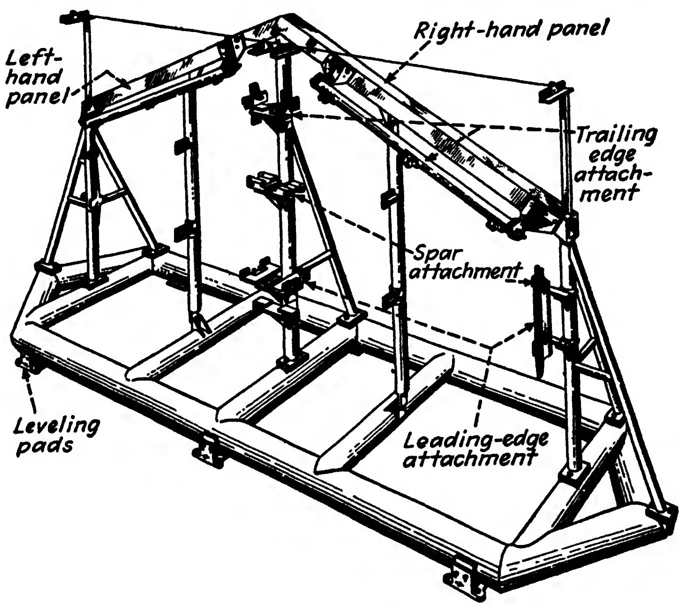


FIG. 12.—Fixture for right and left outer panels of the Lancer plane. Note rigid construction.

Locating plates have been welded to the inner formed tube and position the bulkhead, as can be seen. These stands are adjustable by means of the telescoping lower member, to handle ring frames of various diameters.

TUBE-WELDING FIXTURE

Many parts of modern planes are made of steel tubing, welded into various subassemblies. One such subassembly is shown in Fig. 14, and the details of the fixtures can be easily traced in the perspective sketch above it. The fixture itself is made by

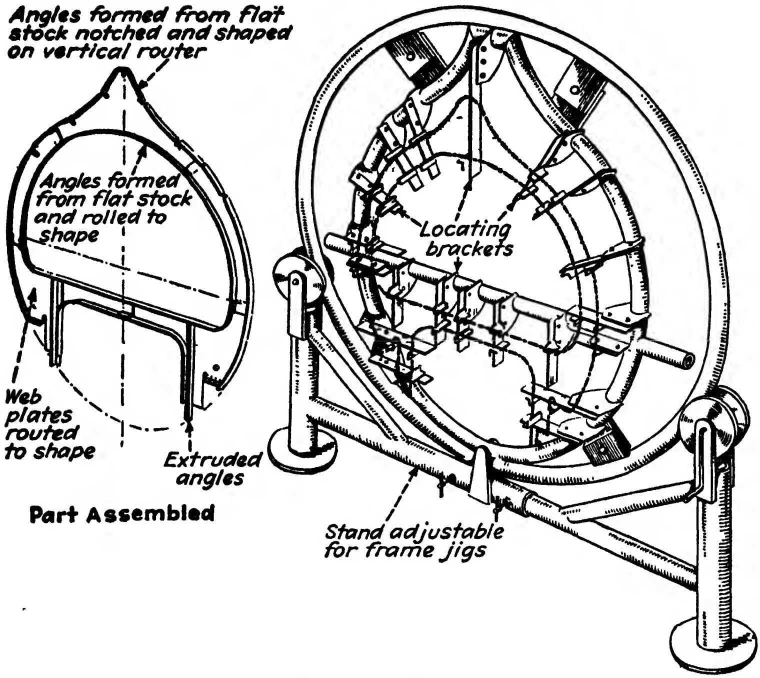


FIG. 13.—Fixture where bulkheads are assembled.

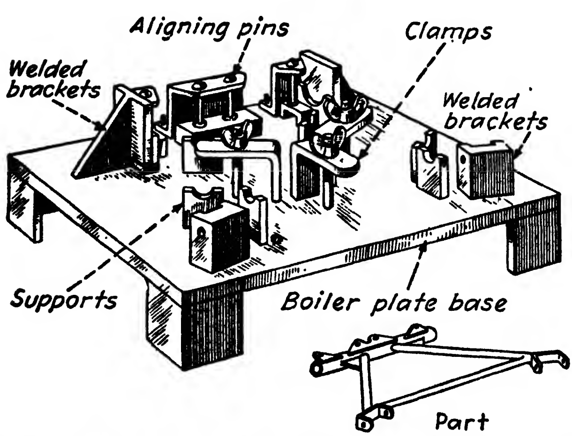


FIG. 14.—One of many fixtures for holding tubing to be welded into subassemblies. The part is shown below the base of the fixture.

welding different blocks and angles to a flat base plate. A study of the supports with curved surfaces to receive the tubing and the clamps and aligning pins makes it clear how the parts are held so as to ensure their correct location in the subassembly.

HUGE ASSEMBLY FIXTURES FOR BOMBERS

Building the huge wings for the Flying Fortresses, technically known as the B-17 Douglas bombers, involves the use of fixtures

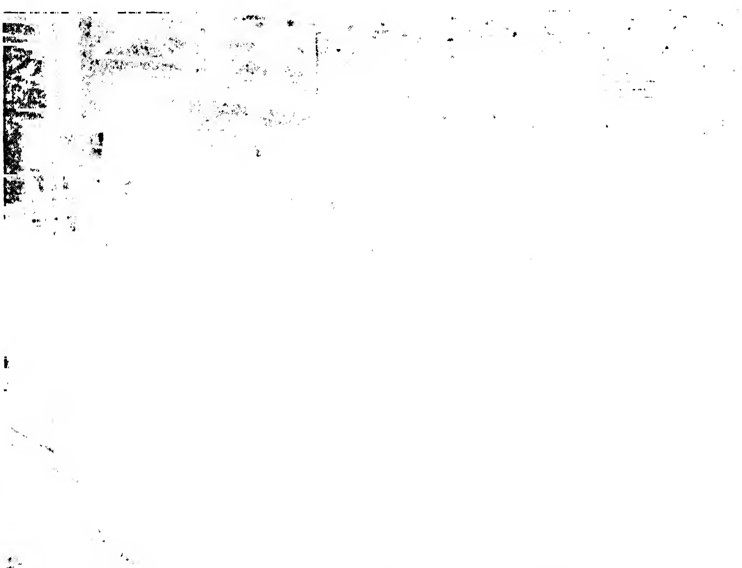


Fig. 15.—A three-story assembling fixture for Douglas bombers.

unlike any we have seen in ordinary shopwork. The main fixtures are three stories high. Part of this fixture is shown in Fig. 15. There are three working levels, the lower level being five steps above the floor.

The wings are at right angles to the tubular structure shown. The leading edge of the wing is at the bottom, the trailing edge being seen projecting above the third story of the fixture. Each level of the fixture is supplied with electrical connections and with air outlets to permit portable tools to be used at any point. As will be seen, the fixtures are built up of welded tubular construction, cross-braced to secure the necessary rigidity so that

accurate locating surfaces may be provided for all the elements that go to make up these huge bomber wings.

The front and rear wing spars are first put into place. These are held by pins in fittings which represent the positions of the fuselage and outer wing connections. The sections of the fixture

FIG. 16.—Here rib assemblies go into the lower story of the big fixture.

carrying these locating points are removable and go with the wing when it is removed from the fixture. They are, of course, removed and replaced before the new wing spars are put in place for the next assembly.

With the rib assemblies placed in the fixture, the corrugated subassemblies shown in Fig. 16 are put in place at the lower floor of the three-story fixture. These subassemblies have been completed in other fixtures. These corrugated assemblies are

cut out to receive the gas tanks. As will be seen in Fig. 16, the work of installing these subassemblies can be done entirely by women.

When the primary wing assembly has been completed, the catwalk at the end of the fixture is removed and the end gate is

FIG. 17.—Moving the completed wing framework out of the big fixture.

swung out of the way to provide a clear opening for the removal of the wing. The whole wing is then picked up by a crane (Fig. 17) and moved endwise through the opening provided. The wing is then carried to the beginning of the wing-assembly line and transferred to lifting jacks. While the wings are resting

on the jacks at the beginning of the assembly line, they are fitted with lifting brackets at each end. The wing is then lifted on jacks, and hooks on the holding bracket are attached to an overhead conveyor which is power-driven. There are many other fixtures, but none that compare in size with those illustrated.

FIXTURE FOR ADJUSTING CONTROL SURFACES

To avoid the necessity of leveling the whole plane while adjusting the control surfaces of the Bell Airacobras, Donald Rockwood designed the fixture shown in Figs. 18 and 19. Steel

FIG. 18.—This fixture saves time in adjusting the control surfaces on the Bell Airacobra.

tubing with welded joints made it possible to keep the weight low so that the fixture might be easily handled by two men. Figure 18 shows it in place on one of the elevators, and Fig. 19 shows details—clamping screws, locating pads, and the elevator and rudder quadrants.

With this fixture in place, as in Fig. 18, the rudder is in the center, and its movement can be checked by the horizontal rudder

quadrant, shown in Fig. 19. This rudder quadrant can be removed so as to avoid dropping the whole fixture down over the rudder. Instead the fixture is put in place from behind and the quadrant slipped into place by telescoping one tube in another.

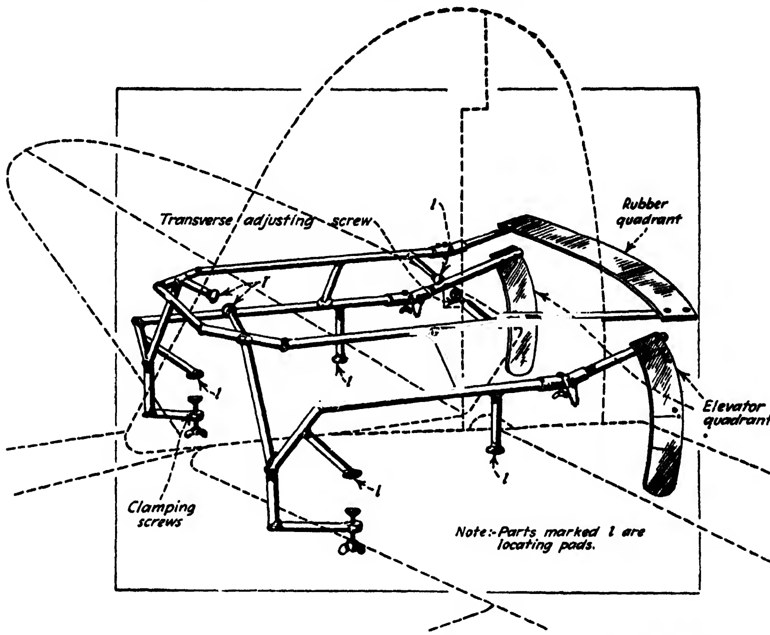


FIG. 19.—Details of the Airacobra fixture with the control surfaces shown in outline.

As will be seen, the elevator quadrants have three graduations: zero, 15 deg. below zero, and 35 deg. above the zero mark. With the fixtures in place, a workman behind the elevator signals the one in the cockpit who is adjusting the control cables so as to give the desired movements.

LARGE AIRPLANE FIXTURES

The extensive use of fixtures in the building of large airplanes during the war brought out many ingenious devices. Although normally called jigs in the airplane industry, they are really large fixtures. Their size imposes many problems on their designers and builders.

The Victory Aircraft Company, Ltd., of Malton, Ontario, near Toronto, were very successful builders of the large 4-motored

Lancaster bombers and made them completely interchangeable. This was true not only of those built in this plant, but those built in Malton were interchangeable with similar planes built in the English plant of A. V. Roe, Ltd. This unusual feat not only helped the manufacture but was also of great value in replacing wings and other parts in the airfields in various parts of the world.

This unusual interchangeability was secured by the use of extremely accurate fixtures in which mating parts were so accurately maintained that, when frames and other parts were aligned, their connecting bolts could be inserted without reaming or machining of any kind. And this in spite of the fact that some of these sections were 24 ft. long.

The Victory plant used welded steel members for its fixtures although the British plant used cast iron. These steel parts were designed by bridge engineers and had known deflection and twist under load. They were built from standard shapes as far as possible. As will be seen, a triangular form of beam was used to secure maximum stiffness. Five types of equipment were employed, as follows:

1. *Drill References.*—These are masters from which production drill jigs are drilled, reamed, bushed, and inspected. In the case of spars and other members over 10 ft. long, and where the limits on essential dimensions are very exacting, the drill references and the drill jigs are made of duralumin to compensate for temperature changes. This practice avoids parts that will not fit: differential expansion of a 30-ft. dural spar in a steel jig amounts to 0.046 in. between 60 and 80°F.

The dural drill plates float on a steel bed. Later in the assembly fixture the drilled spar is picked up by a fixed point at one end (usually the inboard end) and by floating points at intermediate stations.

2. *Mechanical Jig References That Check Jigs, Not Components.* These are commonly used for large subassemblies, which are too bulky or heavy for gaging and involve close tolerances. Jig references are castings, sometimes made from scrap aluminum but most frequently of cast iron to avoid damage. The castings were machined for pickup fittings and for leveling and measuring surfaces that are located as closely as the gage maker can work, in contrast to the afore-mentioned gages which are commonly made to one-tenth the tolerance allowed on the working drawings.

Jig references have these advantages: (1) Assembly jigs in which the pickup points and locating surfaces are accurately set to the jig reference produce components that assemble without fitting. For example, fin-attachments holes in the front and rear spars of the tail plane are jig-referenced with counterparts of the tail-plane spar jig reference. The holes in the two jigs are reamed in their respective assembly jigs, but close-fitting bolts will assemble the two components without further fitting.

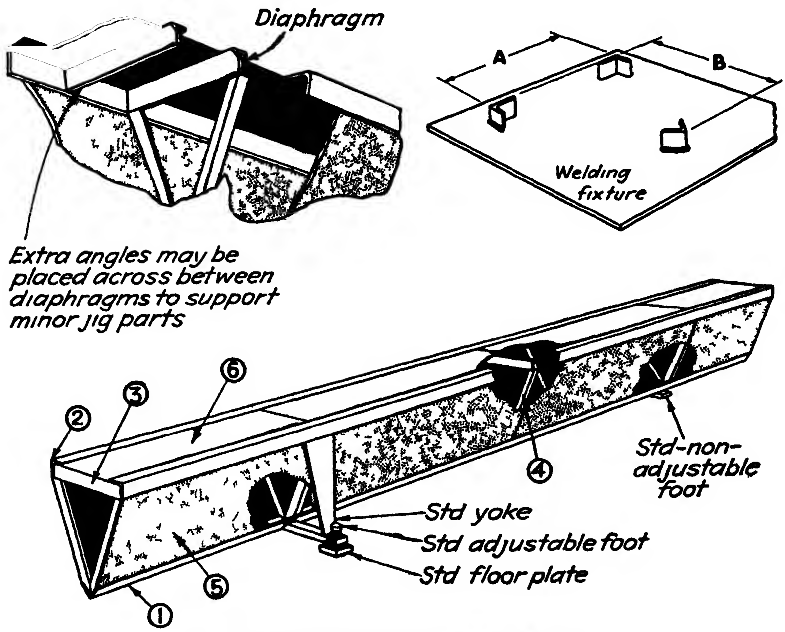


FIG. 20.—Construction of triangular bed.

(2) The jig reference for a part can be set and checked with the jig reference of the counterpart, which is not possible with the gages for two parts.

3. *Optical Jig References.*—For setting up and periodic checking of large assembly jigs, in which the utmost precision is required at widely separated attachment points, optical jig references were brought to a high state of development.

The optical reference equipment consisted of alignment apparatus designed by Taylor, Taylor & Hobson of Leicester, England; very precise jig references to attach to the jig pickups, or attach-

ment points on which the optical instruments were mounted. These consisted of an alignment telescope and a collimator.

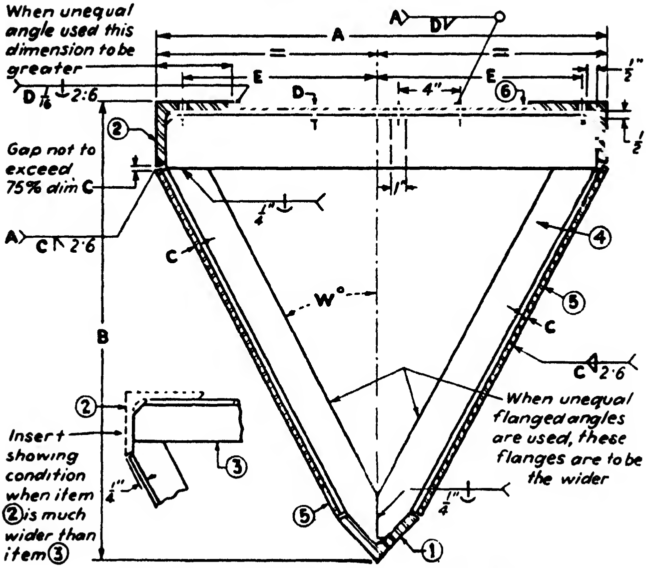
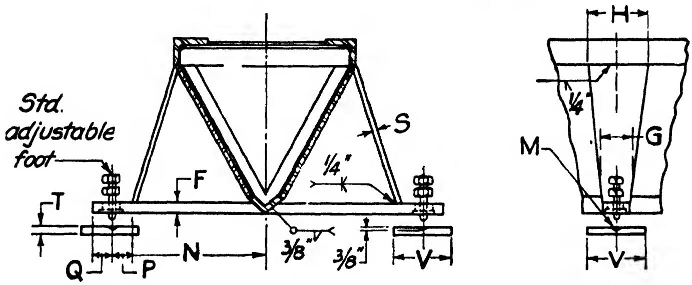


Fig. 21.—Standard dimensions and sections.



Yoke Type	G	M	P	Q	S	T	V	F
Light	3	1/2	2 1/2	2	1/2	3/4	5	1 1/2
Heavy	4	3/4	3	2 1/2	3/4	1	8	2

Fig. 22.—Arrangement of support yoke.

They also used an English-type Johannson micrometer trammel, or sectionalized inside micrometers.

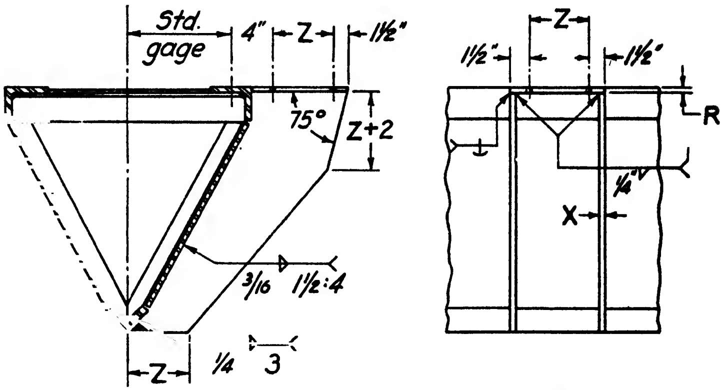


FIG. 23.—Attachment points, column over bed center.

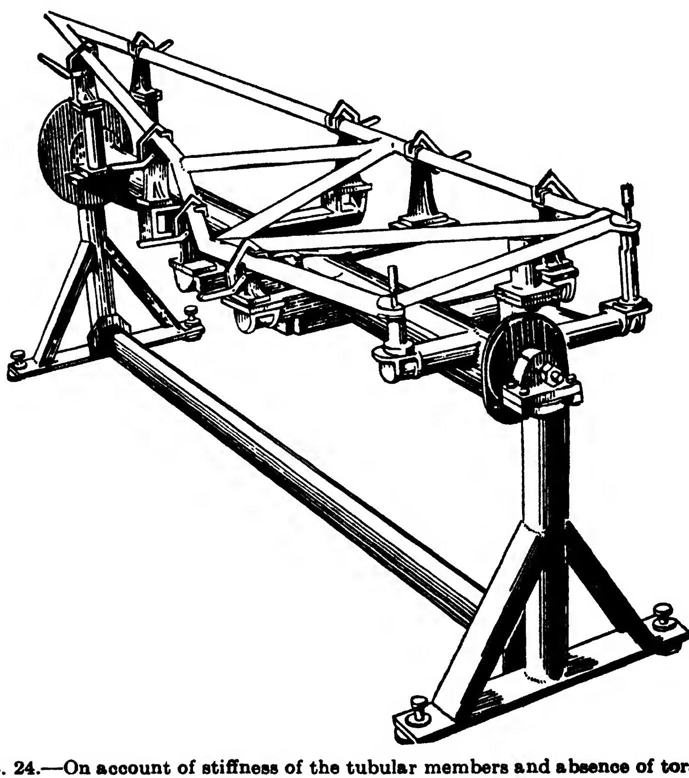


FIG. 24.—On account of stiffness of the tubular members and absence of torsion, indexing need be done only at one end.

These optical jig references would detect a misalignment of 0.010 in. at 50 ft. and lack of parallelism within 6 sec. of arc, or 1 part in 30,000. The mounting brackets of the references included trammel pads which were held to total tolerance of 0.0002 in. with respect to the axis of the attachment holes fitting the pickup in the jigs. With the micrometer trammels, it was possible to measure within 0.005 in. between trammel pads spaced 30 ft. apart and within 0.0002 in. in 5 ft.

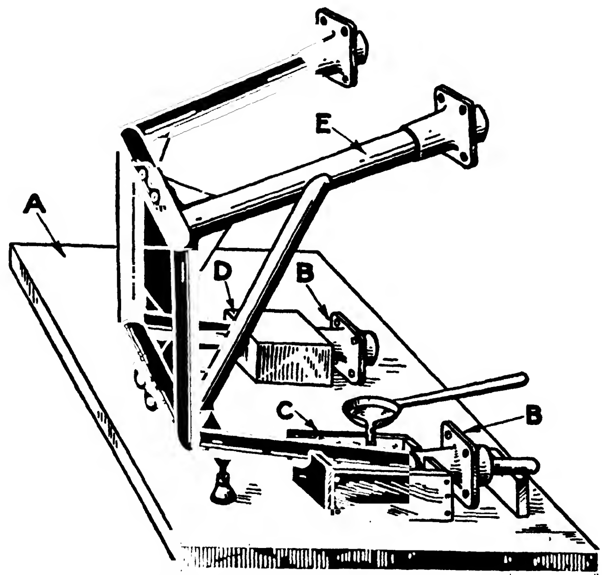


Fig. 25.—Holding irregular shapes by pouring low-melting alloy around lower legs and using small screw jacks as shown.

A complete checkup of the pickup points in a 30-ft. wing jig could be made in approximately 2 hours. Besides the speed and accuracy possible, the use of optical references permits the equipment to be left largely in place if repairs must be made. This greatly reduces the time for repairs.

4. *Gages That Check the Component.*—These were used for small parts and subassemblies where the tolerance was sufficiently wide. Lightness and rigidity are needed in such gages. Tubular-steel framework and cast-iron brackets to support non-adjustable locating pads or bushing plates were used. If

deflection or wear occurs, the gaging element must be remachined. No shims can be used. Where the weight permits, the gages for

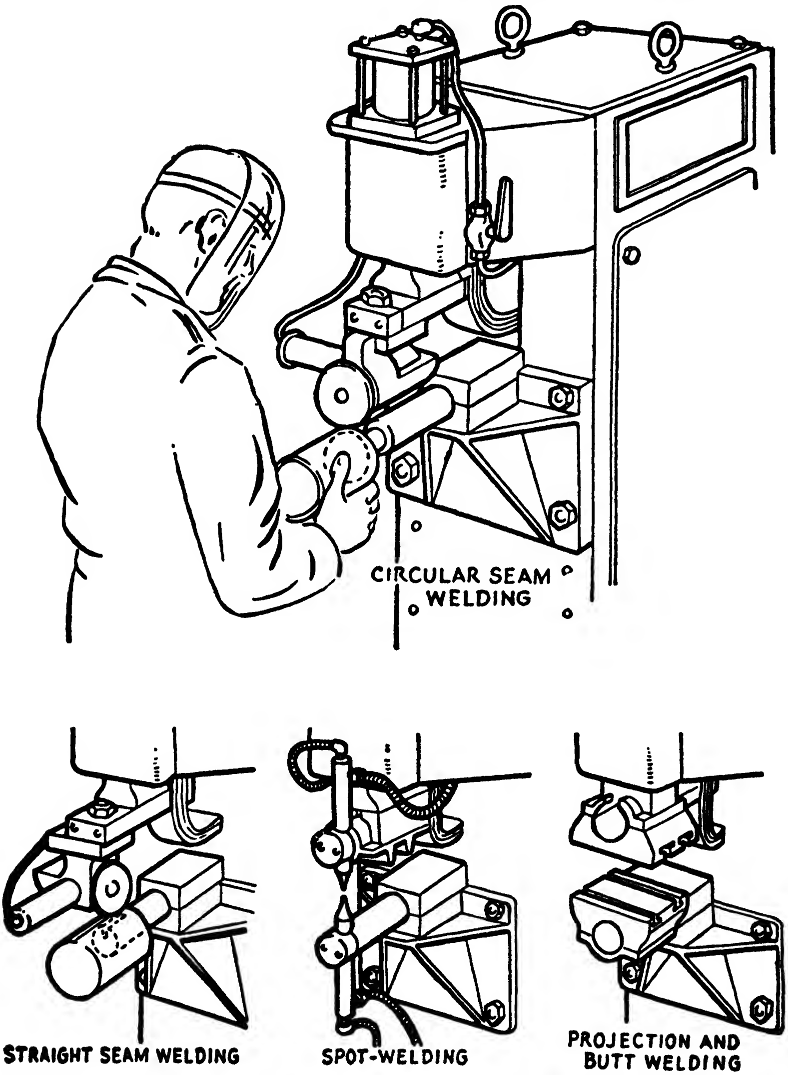


FIG. 26.—Showing how, with a few minor changes, a standard welder can handle a variety of jobs.

parts and assemblies under 15 ft. long were taken to the component. In other cases the part was taken to the gage.

5. *Approved Jig-produced Parts Used as Substandards or Patterns.*—These were not employed for components where the tolerances were very close. Some dural parts could be reworked to make an interchangeability setting fixture for assembly jigs. The dural structure was considered better than steel for this purpose as the coefficient of expansion was the same as the work.

Beds of Large Fixtures.—The beds of the large fixtures were made of triangular cross section as shown in Fig. 20. The weld-

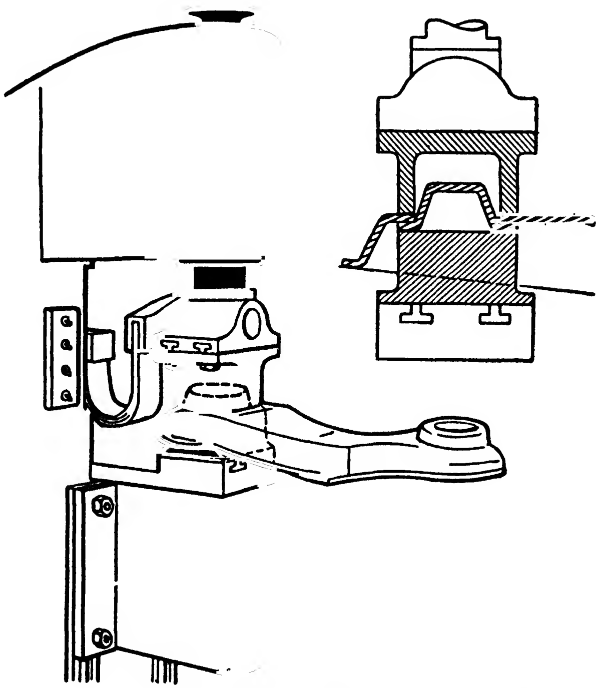


FIG. 27.—Projection welding of Nash front-end suspensions.

ing fixture is also shown. Details are given in Figs. 21 to 23. These are presented as suggestions for fixtures for any other large work where great accuracy is required.

The use of the optical method of alignment requires great care in making the jig references, the limit for misalignment being 0.0005 in 24 in. The optical instruments were located accurately by use of a double-taper pin, which was found very satisfactory.

A heavy type of tubular construction is shown in Fig. 24 for a roll-over jig where the parts are rather heavy. This design

had sufficient resistance to torsional and flexing stresses to carry the load shown.

Holding Tubular Parts for Machining.—It was necessary to machine the mating, or attaching, surfaces on two large, welded tubular airplane parts. The fixture had to be inexpensive as but few parts were to be made. F. W. Fromm devised the

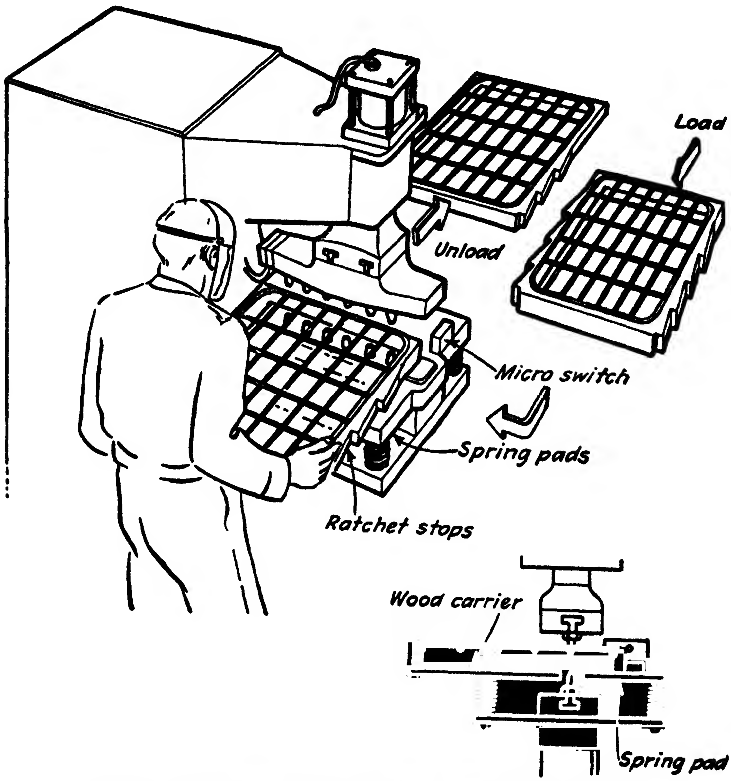


FIG. 28.—Spot welding wire racks accurately and quickly.

method shown in Fig. 25. The parts were approximately 4 ft. square and 5 ft. high, and the work had to be done on a No. 3 milling machine. This presented a difficult setup problem. It was solved by leveling the jig up on a surface plate, and pouring hold-down blocks around two of the tubular legs.

The assembly *E* was set up on a surface plate *A* in the correct position for machining. Then the box or mold *C* was placed

around the tubular legs as close as possible to the fittings *B*, which were to be machined. All gaps between the ends of the box and the part were filled in with clay, then the box was poured

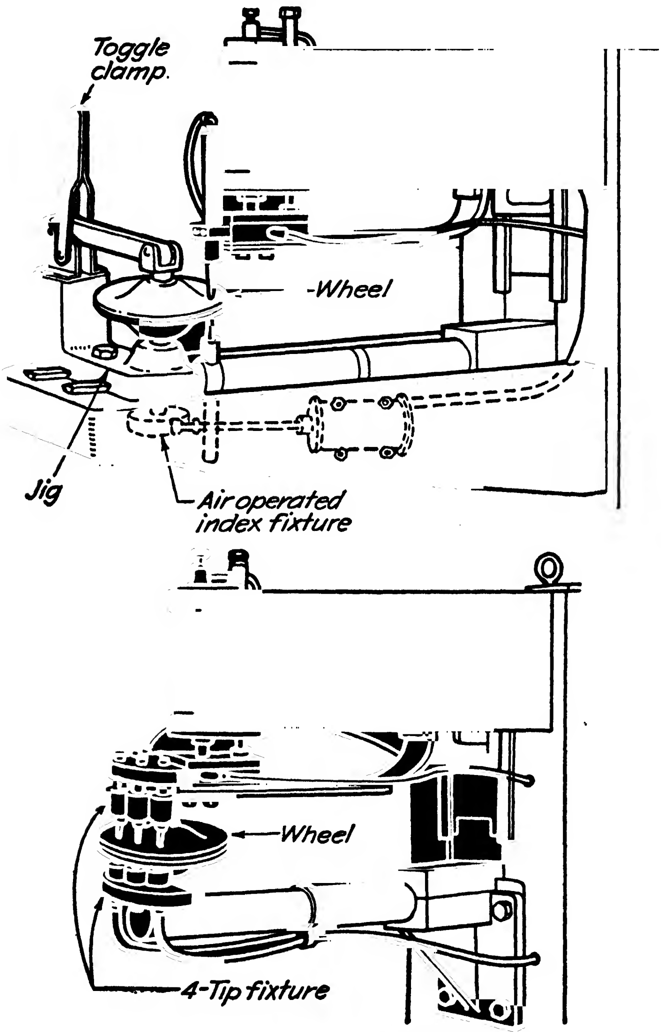


Fig. 29.—Fixtures for welding circular parts.

full of Cerro Bend. After the Cerro Bend hardened, the jig was set up on the milling machine and lined up parallel with the table. Hold-down clamps were then placed directly on the Cerro

Bend blocks *D*. Since Cerro Bend has a melting point of about 180 deg., it was melted off with boiling water after the machining was completed.

This method avoided the use of expensive fixtures on this particular job, and has since been used where a limited number

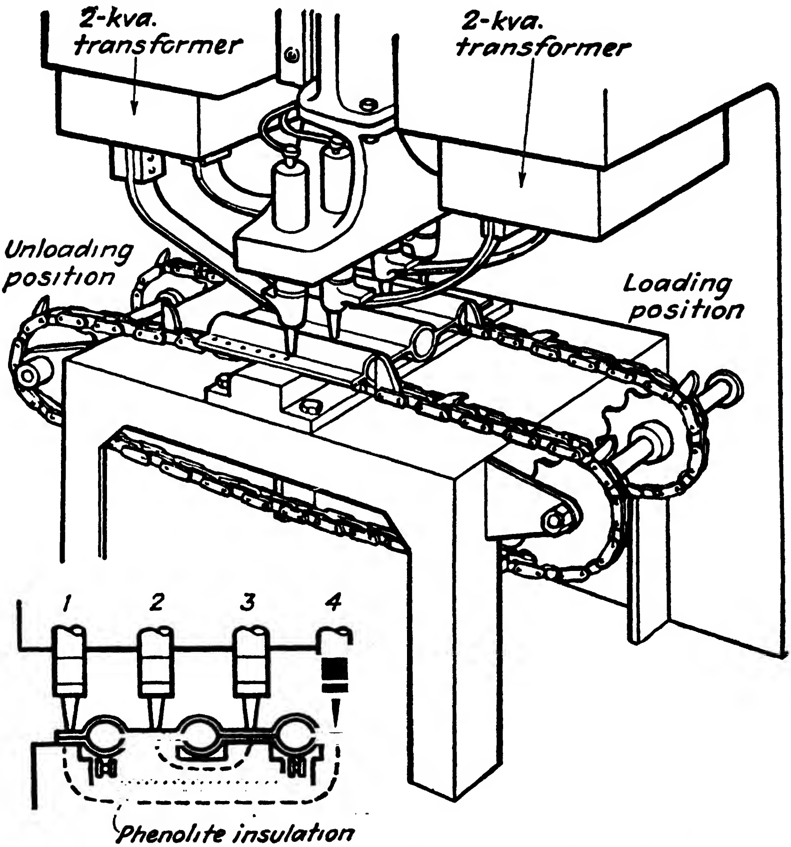


Fig. 30.—A method of double series welding. Two transformers, with interlocked controls, feed four welding points.

of irregular-shaped parts have to be machined. It works particularly well on tubular jigs used in the fabrication of aircraft subassemblies, since the jigs can be held absolutely rigid without distorting or bending the tubular section. This method has also been used to machine light castings, because it eliminates chatter and holds the part firmly during all machining operations.

Fixtures for Welding Operations.—Wherever it is necessary to produce duplicate work consisting of two or more pieces in any quantity, it becomes necessary to design use fixtures to hold them in position during the assembly. Welding is no exception to the rule, and the growth of electric welding in producing many types

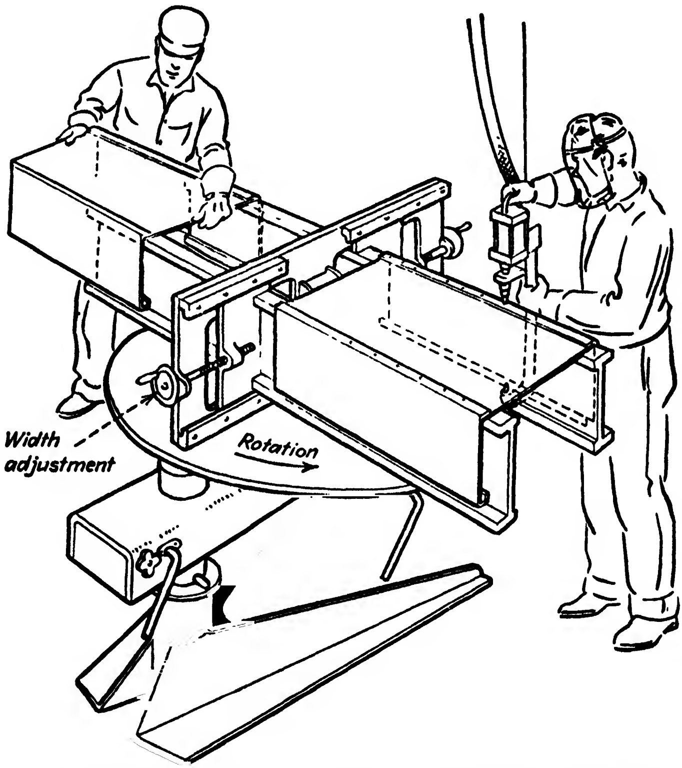


FIG. 31.—Various width cabinets are welded on this pedestal type jig with hand wheel adjustments.

of manufacture brings this into the field of the jig designer and builder.

Without the use of suitable fixtures, the use of resistance and other welders is greatly limited. Ed Riley, welding engineer of the Specialty Equipment and Machinery Company, says that the range of work that can readily be assembled by standard welders is limited only by the designer of jigs and fixtures.

Illustrating this contention, he shows a number of such jigs and fixtures, which have greatly increased the usefulness of the

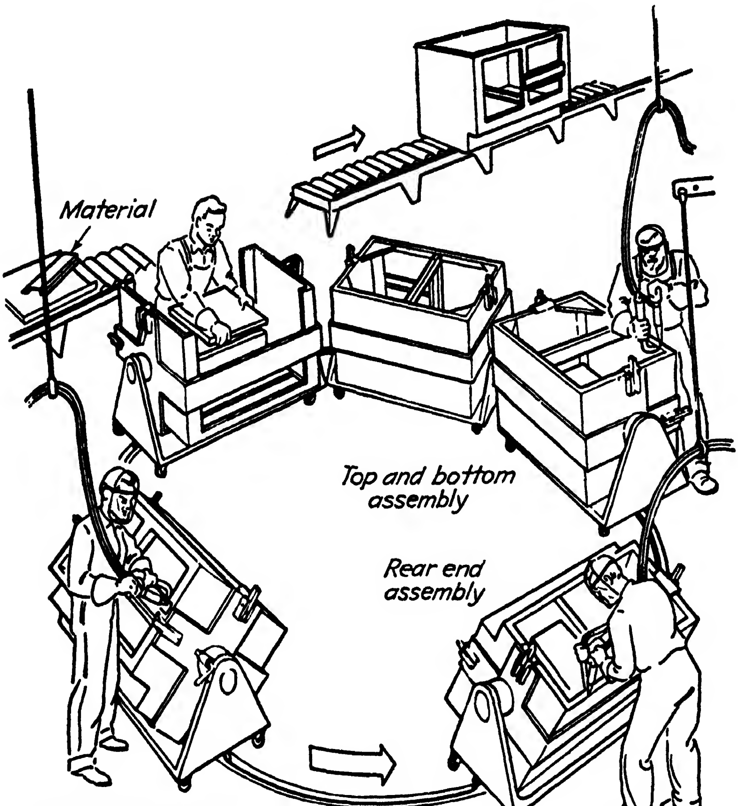


FIG. 32.—Trunnion-type assembly fixtures and standard gun welders allow rapid work on a circular track.

welders in his own plant (see Figs. 26 to 32). The captions tell the story of their usefulness.

Section 6

INSPECTION AND TOOLROOM SYSTEMS

CHAPTER XV

FIXTURES FOR INSPECTING WORK

Proper fixtures are as necessary for inspecting work after it has been drilled, milled, or otherwise machined as they are for doing the machining operations. They vary widely in construction and involve the use of plugs for size as well as for location of holes and of different types of indicators to show whether the amount of variation is within the allowable limits.

A few examples of inspection gages and methods follow.

Inspection Fixture for Hole Location.—The fixture shown in Fig. 1 is for inspecting the alignment of holes in the wishbone

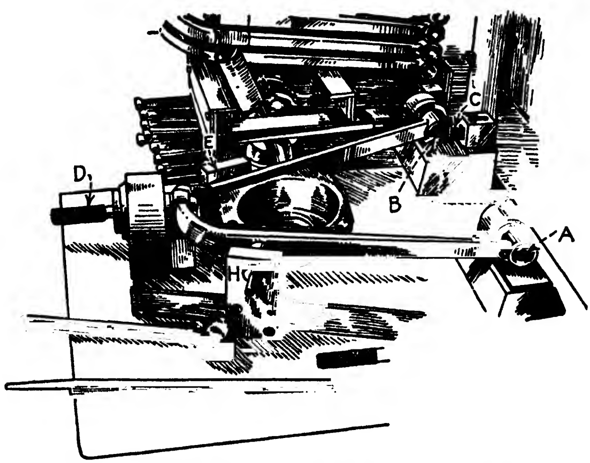


Fig. 1.—Gaging fixture for knee-action wishbone.

used in some types of knee-action front-wheel supports. The end holes are placed over the pins *A* and *B* with a side movement, and the wishbone swung down so that the plug *D* can enter the hole at the end. If the plug enters correctly and the pins *E* and *H* contact the sides of the fork, the alignment is correct. The slide *C* merely holds the bearing *B* in place on the pin while the fork is being swung down into the horizontal position.

Inspection of Jig Bushing Holes.—In checking center distances, time may often be saved by first determining the degree of refinement needed in computing the subtended angles. Toolmakers and floor inspectors who have occasion to check jig bushing holes in series directly after horizontal boring while the job is still strapped to the machine table are likely to have trouble when computing the direct center-to-center diagonal dimension between holes unless they have some means of limiting the amount of interpolation. Here is the method worked out by Walter Wells.

On small jobs, the 1-min. divisions on regular trigonometric tables are good enough even for precision work. But on jobs where the center distance between holes is 3 in. or over, significant errors will creep into the calculation. This is because the length of the arc varies in direct proportion with the length of the sides of the subtended angle. When the computation for the angle does not come out even in degrees and minutes, the difference will cause an error unless taken into consideration. For example, if the sides are 20 in. long, a difference of 1/2 min. will cause an error of 0.003 in. in the side.

At first thought, the solution would seem to be to interpolate the angle in terms of seconds of an arc. However, this is going to the other extreme, for in most instances the result would be far more precise than necessary. To simplify the computation, Table 1 has been worked out to save time. This shows the degree of refinement for the angular measurement required in relation to the lengths of the side of the angle to give a maximum tolerance of only 0.00029 in.—about one-quarter of a thousandth. The interpolation is given in simple fractions of a minute.

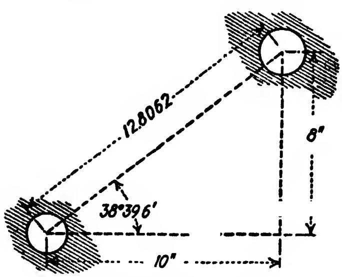


FIG. 2.—Checking location of jig bushing holes.

This table may be easily memorized, as the maximum tolerance fortunately works out so that the fraction of a minute in each case is simply the reciprocal of the longest side in inches.

An example is given in Fig. 2. The base and altitude are given as 10 and 8 in., respectively. It is required to compute

the hypotenuse by first determining one angle in terms that will keep within the desired limits. From Table 1, it is apparent that the angle must be interpolated to an accuracy of tenths of a minute. Figuring on this basis, the value is fixed at 38 deg. 39 min. plus an additional 0.6 min. Using this angle, the hypotenuse is figured as 12.8062 in., which is precise to the limits set.

But had we been content to call the angle 38 deg. 40 min., the nearest value given in most tables, we should have obtained a result of 12.8075 in., a difference of 0.0013 in., which is not permissible because the boring tolerance itself is only 0.002 in.

TABLE 1

Longest Side, Inches	Interpolation, Fractions of a Minute
1	1
2	½
4	¼
10	0.1
30	1/30 (2 sec.)

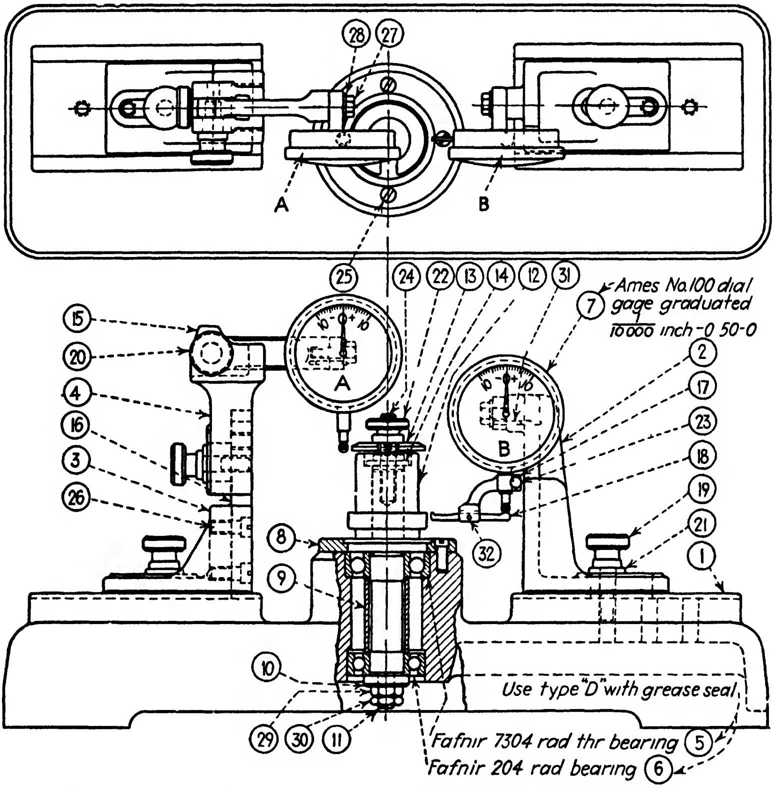
When using an optical dividing head, its limits of accuracy should be kept in mind. For instance, if the instrument will read accurately to 0.5 min., the following error in computation may be possible:

TABLE 2

Radius, Inches	Possible Error, Inches
2	0.0003
5	0.0007
10	0.0015

Inspection Fixture for Sprockets.—The indicating gage or fixture shown in Fig. 3 was built by Taft-Peirce Mfg. Co. for inspecting the runout of the sides of a silent chain sprocket with the bore. The two Ames dial gages *A* and *B* are mounted on suitable supports which can be adjusted by means of the lever which reverses the motion. Details of this inspection fixture are shown clearly and so need no further explanation.

The list that accompanies the illustration was part of the blueprint in the original. This list gives a rather complete description of the parts used. The abbreviations, both as to the materials used, in the third column, and as to the heat-treatments in the last column, are easily understood. This last column also shows which parts are purchased.



DEPT NO	NO. REQ	MAT	FINISH STOCK SIZE	TREAT	DEPT NO.	NO REQ	MAT	FINISH STOCK SIZE	TREAT
1	1	C I	Patt No	Norm.	17	1	MS	13/32" x 1 7/32" x 1 1/8"	–
2	1	C I	Patt No	–	18	1	TS	0 050" x 3/16" x 1 7/8"	Hdn.
3	1	C I	Patt No.	–	19	3	MS	1" Diam x 1 7/8" Long	–
4	1	C I	Patt No.		20	1	MS	1" Diam x 1 15/16"	–
5	1	–	Fafnir #7304 Type D Brng	Purch.	21	3	MS	7/8" Diam x 1/8 Thick	–
6	1	–	Fafnir #204 Type D B'rng	Purch.	22	1	MS	1" Diam x 9/16" Thick	Cyan
7	2	–	Ames #100 Dial Gauge	Purch	23	1	MS	9/32" Diam x 5/8" Long	Cyan
8	1	MS	3 1/4" Diam x 5/16" Thick	–	24	1	CRS	3/8" Diam x 2" Long	Cyan
9	1	MS	1 1/16" Diam x 1 25/32" Long	PH	25	4	Scr	1/4"-20 x 5/8" Fil Hd	–
10	1	MS	1 3/32 Diam x 1/4" Thick	–	26	2	Scr	5/16"-18 x 3/4" Fil Hd	–
11	1	MS	2 3/32" Diam. x 5 5/8" Long	PH	27	2	Scr	1/4 x 20 x 3/4" Hex Hd Cap	–
12	1	T.S	1 7/8" Diam x 2 1/16" Long	Hdn	28	2	–	1/4" Lock Washer	–
13	1	MS	1 3/4" Diam x 7/32" Thick	PH.	29	1	Nut	3/8"-16 Hex - 1/4" Thick	–
14	1	MS	1 1/16" Diam x 1/4" Thick	Cyan	30	1	Nut	3/8"-16 Hex Check-3/16 Thick	–
15	1	MS	3/4" x 1 3/32 x 3 9/32 Long	–	31	2	DR	3/32" Diam. x 11/16" Long	–
16	1	MS	1/2" x 1 1/8" x 4 1/8"	–	32	1	DR	1/16" Diam x 1/4" Long	Hdn.

Fig. 3.—Inspection fixture for silent chain sprockets.

One- and Two-handed Fixtures.—Placing and removing a part to be processed in and out of a fixture always require a number of hand motions. One-handed fixtures are those in which practically all the work-handling motions are made by one hand. Two-handed fixtures are those in which the required work-handling motions are shared by both hands.

Other characteristics being equal—rigidity, accuracy, simplicity—that fixture which most equally divides the work between both hands of the operator will be most productive, since the combined motion time will be approximately split in two. It will

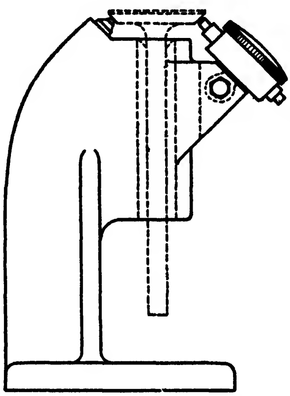


Fig. 4.—Fixture for checking valve seats.

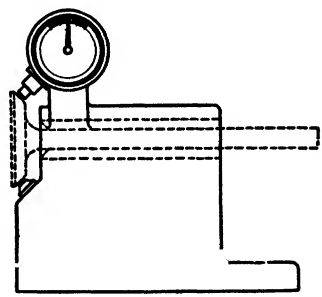


Fig. 5.—Horizontal fixture for same operation.

also be more productive because of causing less fatigue on the operator. This applies in greater degree as the actual handling time represents a greater share of the total operating time and is greatest in that type of gaging or inspection fixture where practically the entire operation consists in handling the work.

Four such fixtures of a simple type are illustrated by Alfred M. Wasbauer in Figs. 4 to 7. Figures 4 and 5 are designed to check the concentricity of seat and stem on a poppet valve; and Figs. 6 and 7, to check the angularity of the piston-pin hole in a piston.

It should be the aim of the designer to obtain smooth, continuous, and duplicate motions for both hands of the operator. This may involve some complication of design; if so, closer scrutiny is indicated to determine whether the increased convenience

and speed of operation will warrant the extra cost involved. It is to illustrate these points that the examples have been chosen.

There is little difference in cost between the two fixtures shown in Figs. 4 and 5, but there is quite a difference between them in speed and convenience of operation. In Fig. 5, the operator will logically place and remove the work entirely with the left hand, using the right hand merely to twirl the stem where it protrudes from the fixture. In Fig. 4 the operator will use one hand to place the work and the other to remove it—these two motions being practically simultaneous—and either hand to twirl the stem. If we allow 3 sec. to twirl the valve in taking a reading and 1½ sec. each to place and remove the valve, we can look for a production gain of about 25 per cent by using the fixture in Fig. 4 over that of Fig. 5.

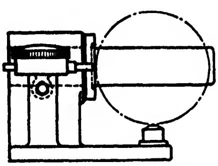


FIG. 6.—Checking angularity of piston-pin hole.

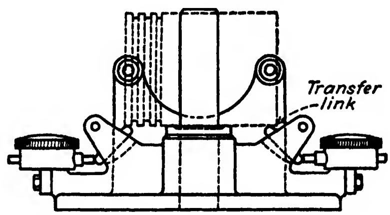


FIG. 7.—Another fixture for the same operation.

Figure 6 is a simpler fixture than Fig. 7, but, being one-handed, it cannot be so fast. The work is heavier than in the preceding case, so it is even more important that the operator use both his hands in order to minimize fatigue.

Motion study as applied to the operation of tools and machines offers opportunities for economy not always fully realized. For the same effort, less vigor is required and less energy expended if the effort is balanced in the body than if it is concentrated on one side or in one member.

In Fig. 7, which, by the way, is practically a duplicate of Fig. 6 except for its different position and the addition of transfer links to the indicators, the operator can pick up and place the work with one hand and remove and set it down with the other, thus forming a smooth and balanced sequence of motions. But in Fig. 6, the work must be handled altogether with the right hand, unless it is transferred to the left upon removal, which would merely burden the left hand without relieving the

right. Since in this case the actual operation consists merely in reading the indicators, it is safe to say that the time saving effected by using the fixture in Fig. 7 will at least equal that cited in the previous example, while the relief to the operator from fatigue will be considerably greater.

Application of Gages.—It is often advantageous to use gages in connection with fixtures that either form part of, or are detachable from, them. Figure 8 shows what is generally classed as a target gage. It is located on the fixture by the hardened

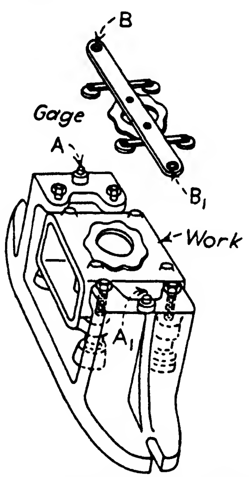


FIG. 8.—Construction of target gage.

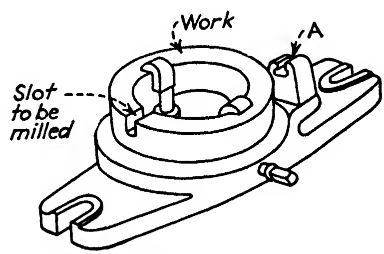


FIG. 9.—Gage on milling fixture for setting gage.

pins A, which fit the bushes B in the gage. The work is then adjusted until the center and small bosses correspond to their respective duplicates on the gage. After the piece is securely clamped, the gage is removed, and the piece may be milled on its locating points as well as on the two sides.

The milling fixture shown in Fig. 9 has a fixed gage A, by means of which the cutter may be set to mill the slot in the ring, which must be directly in line with the center. When the cutter has passed through the gage A, the table is lowered, moved forward, and raised until the cutter is in the correct position to mill the slot to the required depth. The slot is cut on only one side of the ring, and the gage is quite clear of the cutter after the job is once set.

A case where the gage is hinged to the fixture and serves two purposes is illustrated in Fig. 10. The part *B* acts as a gage to which the workman will set his milling cutters, and the part *A* acts as a gage for properly locating the work. After the work is located in its correct position, and the clamp is firmly secured, the gage may be swung out of the path of the cutter, into the position indicated by the dotted lines.

In making the gage, care should be given to the hardening, and all contact points should be ground. The illustration shows an operation, consisting of milling a slot and two sides, that can be successfully accomplished with this style of fixture and gage.

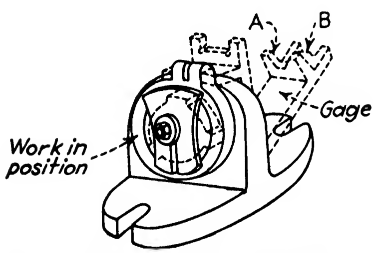


Fig. 10.—Fixture with a hinged gage.

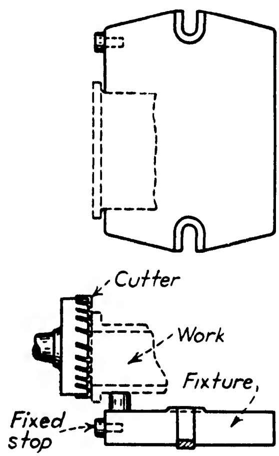


Fig. 11.—Fixed stop for setting milling cutter.

In Fig. 11 is shown the application of a fixed stop for setting the cutter to the correct height, and Fig. 12 illustrates the use of gages attached to the fixture for gaging multiple-height surfaces. For the surface *A*, the fixed stop is used, which in this case is in the form of a bush *D*. For the surface *B*, a plain stop is provided; and for the face *C*, the knurled plug *E* is inserted in the bush *D*. By a combination of bushes of varying heights and a plug, any number of surfaces can be provided for without the stops in any way impeding the movement of the cutter.

A Cutter-setting Gage.—To mill the pieces correctly, however, the cutters must run in such a way that their center line coincides with the center line of the fixture. The little device shown in

Fig.13 is provided to set the cutters. It consists of a cast-iron base *A*, to the top of which a steel block *B* is securely held by a

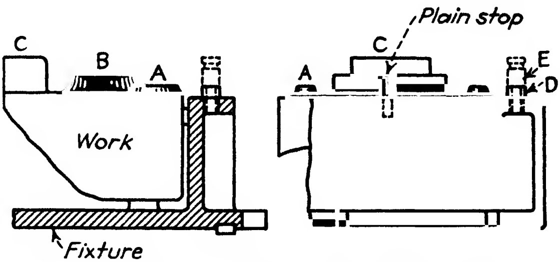


Fig. 12.—Gages on fixture to check different heights.

tongue and groove in connection with the screws *C*. A key *D*, in the bottom of base, lines it up with the milling fixtures so that

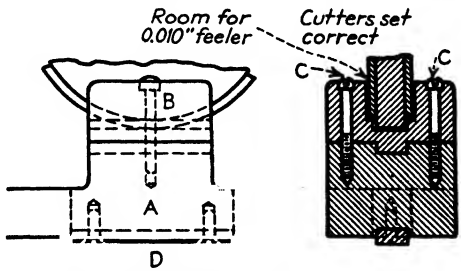


Fig. 13.—Gage for setting cutter.

the gang of mills may be set central by means of the hardened slot in the block *B*, which is made wide enough to admit a 0.010-in. feeler on each side of the mills and underneath, as shown.

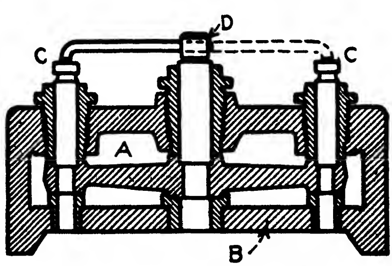


Fig. 14.—Gaging depth of countersunk holes or spot-faced bosses.

Gages for Use in Drilling.—Figure 14 shows a way of gaging the depth of one or more counterbored holes or spot-faced bosses and shows the part *A* in the jig *B*. The holes in the piece have

been counterbored and the plugs *CC* are shown in position, ready for gaging their depth. The height gage *D* rests in the center counterbored hole and is swung from one plug to the other, readily detecting any variation.

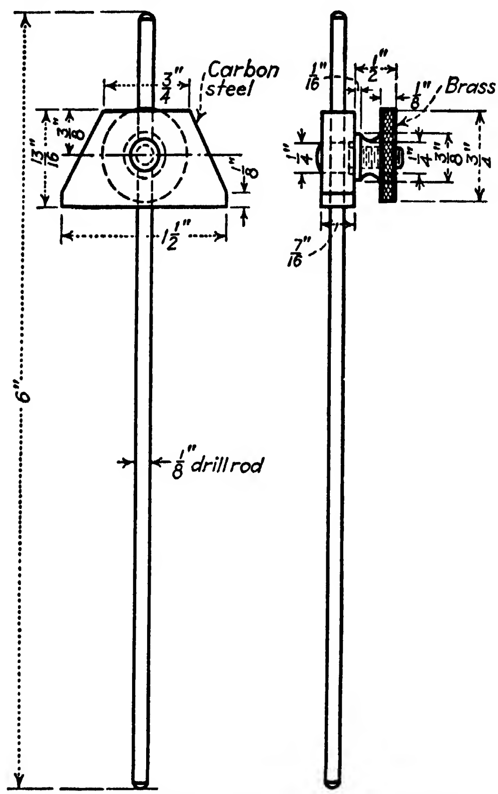


FIG. 15.—Convenient depth gage for drilled holes.

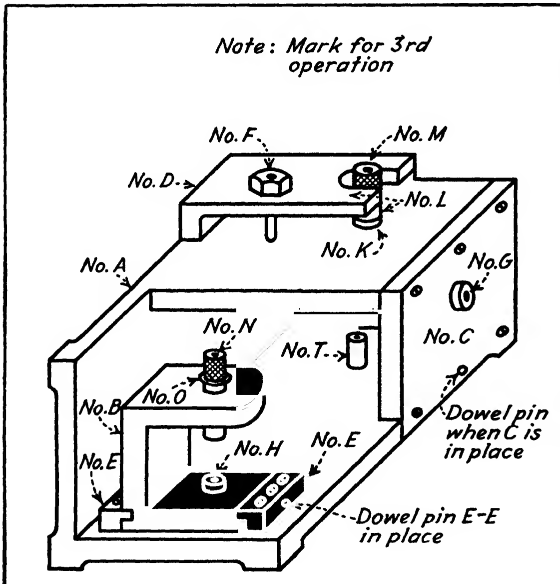
In some instances, these height gages are made with a flush pin gage on the end of the rod, in place of the solid end, and, when very accurate results are necessary, an indicator is attached.

Figure 15 is a small depth gage, such as is used in the drill-press department for determining the depth of a drilled or counterbored hole. It is also used when spot-facing bosses, this being frequently done while the part is still in the jig.

CHAPTER XVI

SYSTEM IN THE TOOLROOM

One of the first essentials of the tool-designing department is that it be run systematically. The following simple method, with various modifications, is in successful operation in some of our largest manufacturing companies.



TOOLS	
SKETCH NO. 9375	
NO. OF DETAIL SHEETS 5	
TITLE Drill Jig	
FOR Lever 10265	
FOR DEPT. #3	ORDER NO. 750
DATE 8-11-36	DRAWN BY A.B.C.
SUPT. O.K. J. Jones	TOOL DESIGNER A. Brown
STANDARD AND SPECIAL TOOLS REQUIRED WHEN THIS TOOL IS IN USE	
# 12 Drill	
$\frac{31}{64}$ "	
$\frac{27}{32}$ "	
0.500 Reamer	
0.875 "	

FIG. 16.—Sketch of fixture and instructions.

The part is carefully drawn full-size, and the jig laid out. The drawing is then inspected by the chief tool designer, and, after meeting his approval, the sketch is made as follows:

1. A perspective view is as shown in Fig. 16, sketches being made by the use of three sheets of carbon paper underneath. One of these is a tissue paper so that blueprints can be made from it. Another carbon copy goes to the toolmaker, and the original copy is retained for the file in the tool-designing department.

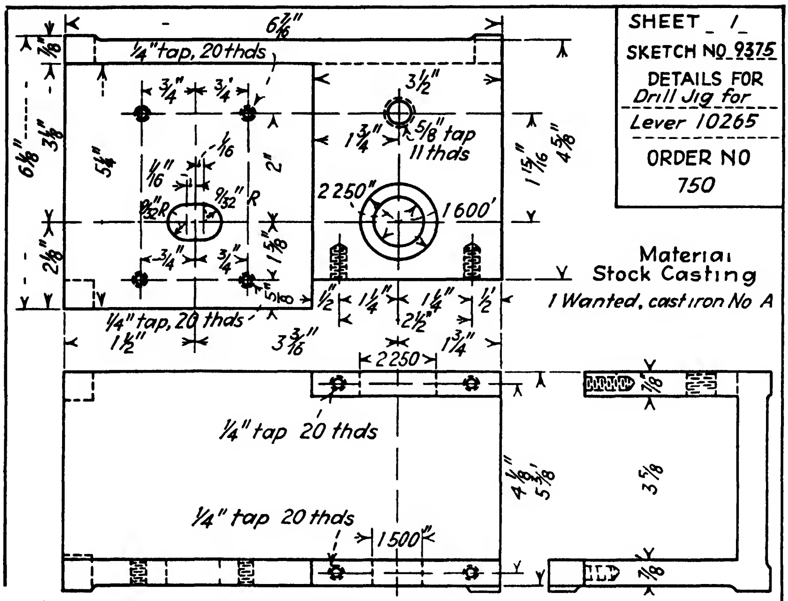


FIG 17 —Sheet of fixture details

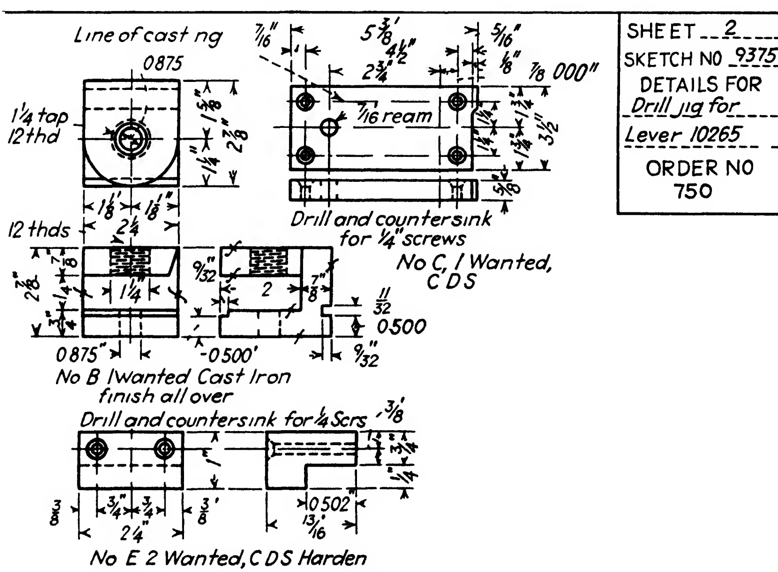


FIG 18 —Detail of sliding piece

2. The next operation is to make a pencil and one carbon copy only, of all detail parts to be finished on milling machine, shaper, lathe, etc. All forging or special parts are then placed again on separate sheets, as shown in Figs. 17 to 21.

3. All of these sheets are given the tool-sketch number and entered in the tool record. Then everything is checked, and the number of the operation for which the tool is made is placed on the perspective sheet.

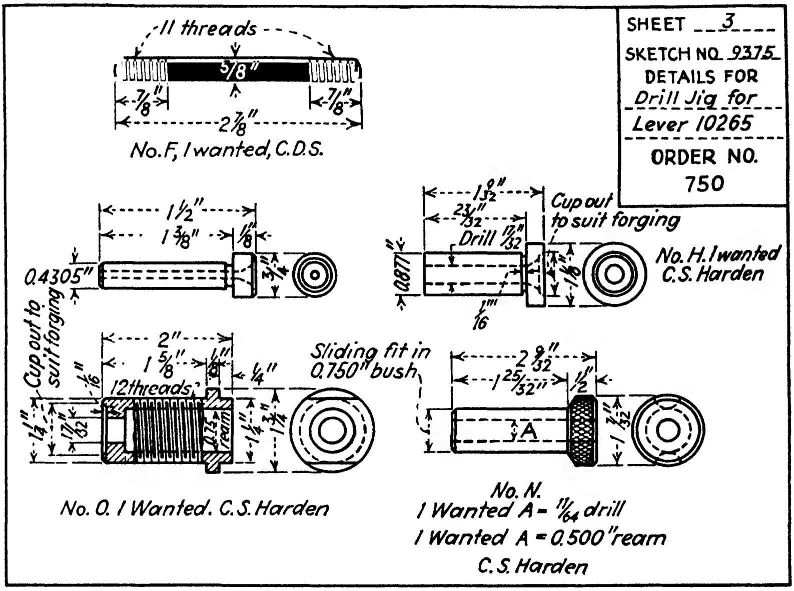


FIG. 19.—Bushing and bolt details.

4. A blueprint is made from the tissue copy of the perspective sketch and sent to the tool store or tool crib, so that the man in charge always has a means of knowing just what the tool looks like. This is extremely convenient in case a tool has been accidentally put in the wrong bin or misplaced, as the sketch gives a much better clue than any description possibly could.

5. Every sketch must be O. K.'d by the chief tool designer, the toolroom foreman, and the superintendent, after which they can be sent to the cost department for orders.

6. When the orders are received, they are given a coat of shellac and then turned over to the toolroom, and the tool is made.

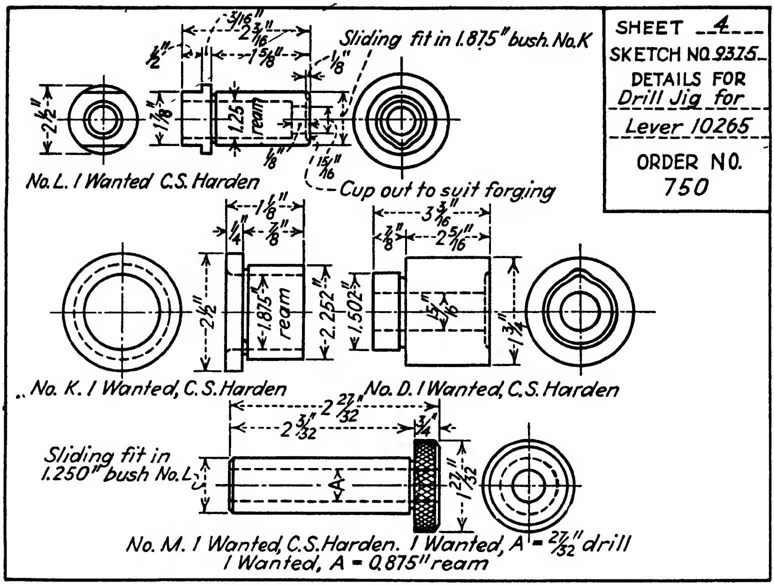


FIG. 20.—The slip bushings used.

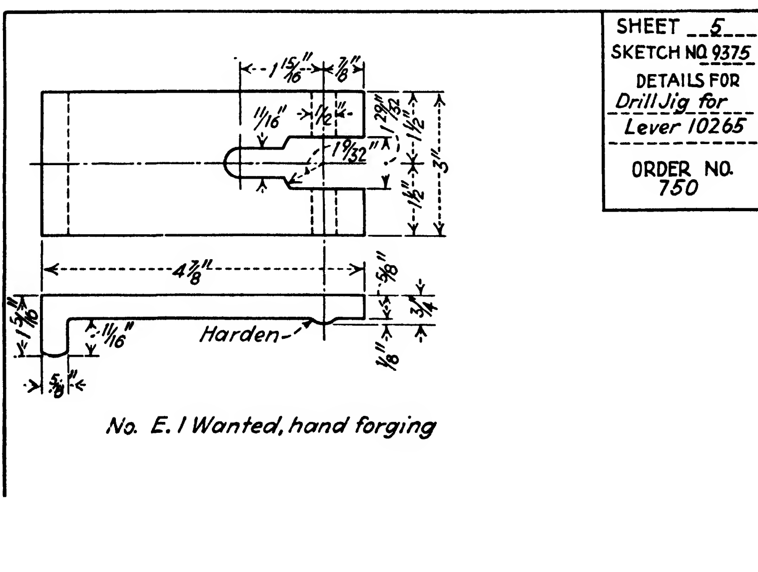


FIG. 21.—Details of forged clamp.

Tool-designing Department Accessories.—The numbering of the tool-record book and tool sketches can be done with a duplicate numbering stamp.

The tool sketches are made on an ordinary 8- by 10-in. scratch pad, and a rubber stamp can be used for the heading of the perspective sheet as shown on the sketch in Fig. 16 and for the detail sheets as shown in Figs. 17 to 21.

In conjunction with this, a series of rubber stamps will be found very useful and helps to give the sketch a neat appearance in case any note such as VOID, RUSH, HOLD UP, or TEMPORARY is desired to be added to it.

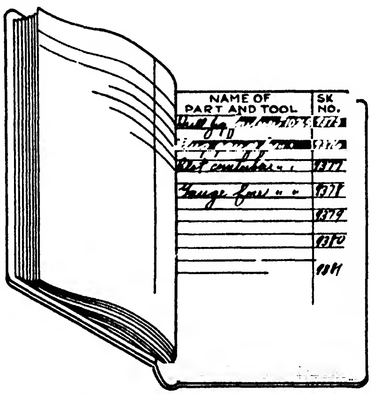


Fig. 22.—Book for tool records.

In conjunction with the sketching, a good drafting machine is very necessary to assist the draftsman in producing quick work.

With the foregoing system, it is remarkable how quickly a sketch can be turned over to the toolmaker. It often happens that a temporary jig, arbor, pin gage, or other tool which is wanted in a hurry does not require a layout but simply a sketch giving the toolmaker the necessary dimensions and that important point of having a record of the tool.

Tool-record and Operation Sheets.—The tool record consists of a well-made book with the numbers running consecutively, as shown in Fig. 22. The sketch gets its number from this book; after which the tool is entered on a card as shown in Fig. 23, and this card is placed in a reference file as shown in Fig. 24.

The tool record simply acts as a check in taking out numbers and prevents a number from being taken out twice.

The reference card is filled under the part number and is consulted in case one wishes to know what tools are made up for that particular part.

The operation that each piece of work undergoes should be decided in this department and is then entered upon the opera-

LEVER	10265
Name of Tool	Sk. No.
Drill Jig	9375
Plug Gage	9376
Pilot counterbore	9377
Gage	9378

Fig. 23.—Reference file card.

tion sheet, as shown in Fig. 25. The sketch is stamped accordingly with the sketch number taken from the tool record and the number of the operation taken from the operation sheet.

There are several styles of operation sheets or cards, and these are generally made to suit the condition governing the factory.

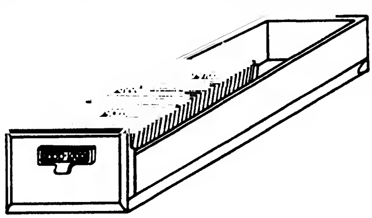


Fig. 24.—Card reference file.

Figure 25 is an example of an operation sheet that can be used to advantage almost under all conditions. It is made of tracing cloth, and the operations, etc., are written upon it with a soft pencil, the reason for doing this being to take care quickly of any changes or additions that may arise; as the sheet is made of

tracing cloth an indefinite number of prints can be distributed among the different departments without any delay.

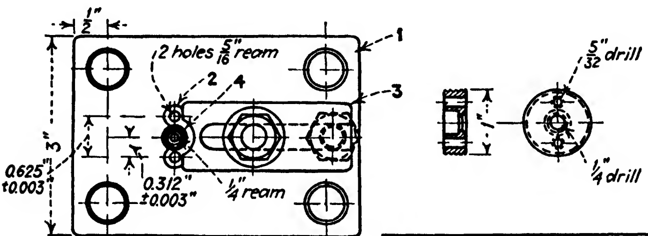
Operations	Machines, tools, gages	Tool no.	(1) Setup	(2) Load and unload	(3) Oper.	(4) Total (2) and (3)
9. Finish face to $\frac{15}{16}$ dim	Lathe Adapter Facing tool Gage for 0.059 to 0.061	 T-8 Std. T-9	4 hr.	$\frac{1}{3}$M	2M	$2\frac{1}{3}$M
10. Mill 0.3125 and 2 sides to $\frac{19}{32}$ dim	No. 2 B. & S. milling-machine fixture Gang cutters and collars 0.3105 to 0.3145 gage Locating gage	T-10 T-11 T-12 T-13	6 hr.	$\frac{1}{2}$M	3M	$3\frac{1}{2}$M
11. Drill, ream, and countersink 0.250 diameter hole	3-spindle drill press Jig Drill and reamers, H.S.S. 0.2495 to 0.2505 limit plug gage Countersink and holder	 T-14 Std. T-15 T-16	2 hr.	$\frac{1}{2}$M	3M	$3\frac{1}{2}$M
12. Drill, spot face, countersink, and tap $\frac{7}{8}$-18	Barnes drill press equipped with Magic chuck, collets and reversing head Jig $\frac{13}{16}$ H.S.S. drill Spec. $1\frac{7}{32}$ combination counterbore and countersink. Spec. $\frac{7}{8}$-18 tap $\frac{7}{8}$-18 thread gage Gage for wall thickness	 T-17 Std. T-18 T-19 T-20 T-21	3 hr.	$\frac{1}{2}$M	6M	$6\frac{1}{2}$M
13. Drill, redrill, spot face, and tap binder screw	4-spindle drill press; 1 spindle equipped with tap head Jig Drills Tap Counterbore $\frac{1}{4}$-28 thread gage	 T-22 Std. Std. Std. Std.	3 hr.	$\frac{1}{2}$M	4M	$4\frac{1}{2}$M

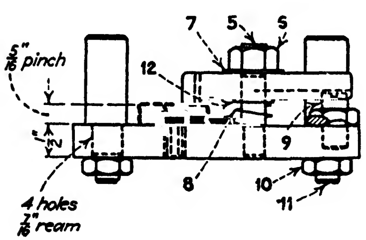
FIG. 25.—Operation sheet of Taft-Peirce Mfg. Co.

When the tool is completed, it is tried out with the part, sent to the tool inspector to be checked up with the sketch, and,

after receiving his O. K., sent to the tool crib or store, ready for use.

What Do Jigs and Fixtures Cost?—The following practical examples from the files of a tool shop furnish a check on costs and help in estimating new work. Jigs and fixtures play such an important part in modern industry, from the viewpoint both of cost and of duplication of parts that data as to cost are essential. In many cases, duplication and accuracy are the deciding factors rather than lowered production costs. In every instance, how-





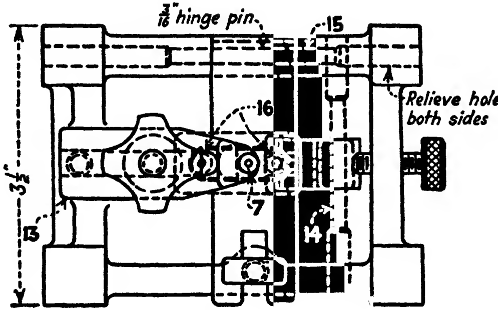
DET. No.	No. REQ	MAT.	FINISH STOCK SIZE	TREAT.
1	1	C.R.S.	1/2 x 3 x 4 1/4	–
2	2	Stock	Briney No 71B for 5/32 drill	–
3	1	C.R.S.	1/2 x 1 x 2 1/2	Cyan.
4	1	D.R.	25/64 diam. x 11/16	Hdn.
5	1	C.R.S.	3/8 diam x 1 3/4	–
6	1	Stock	Style 101-3/8-16	–
7	1	Stock	Style 201-3/8	–
8	1	Spr wire	to suit	Temper
9	1	Stock	Style 4-3/8-16 x 7/8	–
10	5	Stock	Style 102-3/8-16	–
11	4	C.R.S.	5/8 diam x 2 1/4	–
12	1	Stock	Style 201-3/8 (alt. to 5/8 O.D.	–

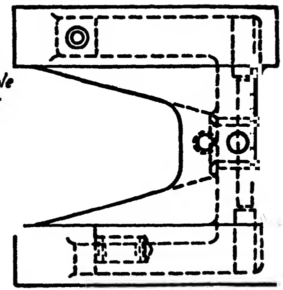
FIG. 26.—Simple toe-clamp fixture and material used.

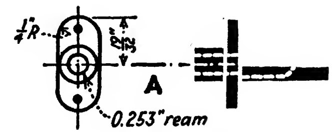
ever, the cost of the jigs and fixtures is an important item, especially when it must be borne by a comparatively small output.

In order to arrive at a basis on which the cost of jigs and fixtures can be accurately estimated, a number of examples are given from the Taft-Peirce Mfg. Co., whose years of experience on a great variety of work in this line make their records of especial value. These examples are taken from their files and cover a sufficiently wide range to assist shop managers and toolmakers in many lines to check up on their own costs. Or the information given can be used in estimating the cost of future jigs and fixtures for new work as it comes along.

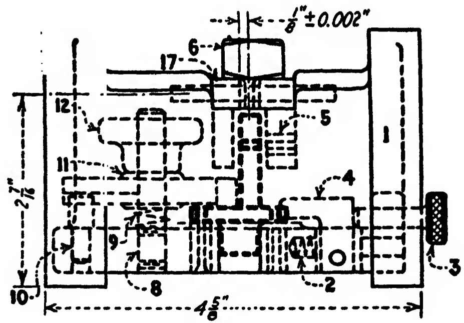
A simple drill jig for drilling two $5/32$-in. holes in a piece held by a single toe clamp is shown in Fig. 26. The base 1, 3 by $4\frac{1}{4}$ in.

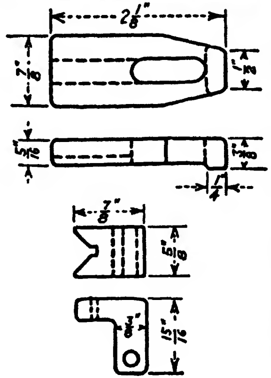






Jack Spring Post
No. 2 Brass

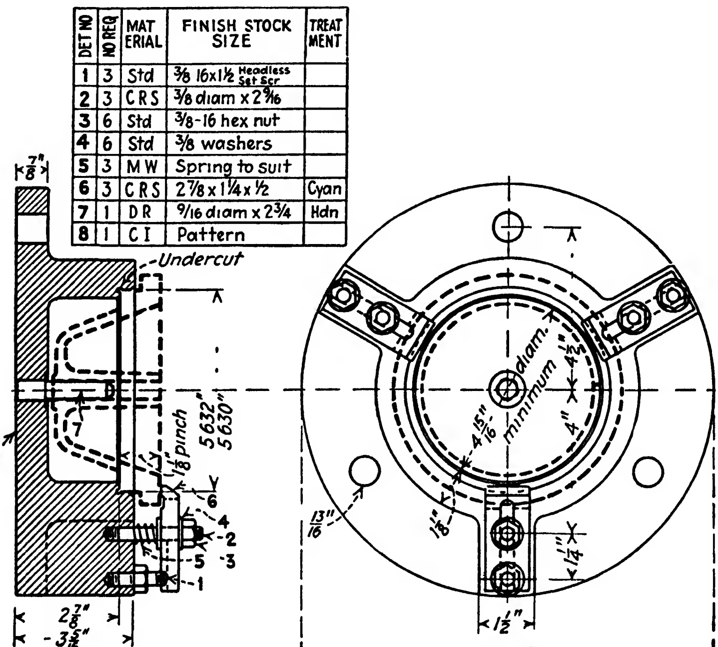




DET. NO.	NO. REQ.	MAT.	FINISH STOCK SIZE	TREAT
1	1	C.I.	Patt.	
2	1	M.W	To suit	
3	1	C.R.S.	[illegible] diam. x 1[illegible] lg.	Cyan.
4	1	C.R.S.	[illegible] x [illegible] x [illegible]	Cyan.
5	1	T.S.	[illegible] diam. x [illegible]	H.-G.
6	1	C.R.S.	[illegible] x [illegible] x 1[illegible]	C.R.S.
7	1	T.S.	[illegible] diam. x [illegible]	H.-G.
8	1	C.R.S.	[illegible] diam. x 2[illegible] lg.	
9	1	M.W.	To suit	
10	1	C.R.S.	[illegible] diam. x [illegible] lg.	Cyan.
11	2	STK	Sty. 201, [illegible] x [illegible]	
12	1	STK	Sty. 324, [illegible], tap [illegible]-18.	
13	1	C.R.S.	[illegible] x [illegible] x 2[illegible]	Cyan.
14	1	D. R.	[illegible] diam. x 1[illegible] lg.	
15	1	D. R.	[illegible] diam. x 2" lg.	
16	2	T. S.	[illegible] diam. x [illegible] lg.	H.G.
17	1	C.R.S.	[illegible] x 1 x 3[illegible]	Cyan.

Fig. 27.—A fixture that required a pattern.

is of cold-rolled stock, as is the clamp 3, which is slotted for the hold-down bolt and grooved for the guide pin 9. The clamp is cyanide hardened. Detail 4, which locates the piece to be drilled, is of drill rod, hardened and ground. The dimensions, tolerances, and materials are shown in each case. Drill bushings, springs, washers, and nuts are from standard stock. The time allowed and the cost of material are given in Table 3.



DET NO	NO REQ	MATERIAL	FINISH STOCK SIZE	TREATMENT
1	3	Std	3/8 16x1½ Headless Set Scr	
2	3	CRS	3/8 diam x 2 9/16	
3	6	Std	3/8-16 hex nut	
4	6	Std	3/8 washers	
5	3	MW	Spring to suit	
6	3	CRS	2 7/8 x 1¼ x ½	Cyan
7	1	DR	9/16 diam x 2¾	Hdn
8	1	CI	Pattern	

FIG 28 —Pot fixture with round base

The drill jig in Fig. 27 is not so simple as the first, because it involves making a pattern for which 8 hr. is allowed. The work is seen at *A* and also in place in the jig. It is centered by its large end positioned by the angular V block 4 and held by the strap clamp 13. Two small holes are drilled in the flange, the bushings being seen at 16. A small hole is also drilled in the small end at 7, and a cross hole at 5. Both the bushing cover 17 and the V block 4 are of cold-rolled steel, cyanide hardened. They are pivoted on pins 14 and 15, the ends of the pinholes being

enlarged for ease in assembling. The schedule of time allowance for the different parts and the material cost is given in Table 4.

Figure 28 shows a pot fixture with a base that bolts to a lathe or boring-mill faceplate; the work is shown by heavy dotted lines. It is located on the central plug and also by the step bearing at the shoulder. The corner of this shoulder is relieved as shown. The work is held by three finger clamps. The construction is simple; the base 8 is of cast iron, 7 hr. being allowed for the pattern; detail 7 is of 9/16-in. drill rod, hardened and ground. Clamp 6 is of cold-rolled steel, cyanide hardened; stud 2, headless setscrew 1, and nuts are standard. Spring 5 is wound to suit stud. The allowed time is given in Table 5.

TABLE 3.—COST OF DRILL JIG. (FIG. 26.)

Required	Part	Time allowed, hours	Material cost
	Cutoff material	0.80	
1	No. 1 { Boring dept.	2.50	
	No. 1 { Toolroom	3.20	$0.10
2	No. 2[1]	1.00	1.50
1	No. 3	3.00	0.05
1	No. 4	1.50	0.02
1	No. 5	0.75	0.02
1	No. 6	.....	0.04
1	No. 7	.....	0.10
1	No. 8	0.75	0.02
1	No. 9	.....	0.05
5	No. 10	.....	0.18
4	No. 11	3.00	0.08
1	No. 12	.....	0.10
	Hardening	1.0	
	Assemble	2.50	
	Inspect	1.00	
		21.00 hr.	$2.26

[1] Part 2 is a standard bushing. The time allowance is for grinding the outside diameter to suit the bored hole.

An interesting templet, carrying 10 standard and two special drill bushings, is seen in Fig. 29. The piece to be drilled, shown at *AA*, gives an idea of the work done. The templet rests on the machined surface *B*, and the plugs 2 and 5 locate it in the holes

TABLE 4.—DRILL JIG COST OF FIXTURE. (FIG. 27)

Required	Part	Time allowed, hours[1]	Material cost
	Cutoff material	1 0	
	No. 1 Grind dept.	4 0	
1	No. 1 Boring dept.	5 0	
	No. 1 Toolroom	5 0	$0 30
1	No. 2	0 5	0 02
1	No. 3	1 0	0 02
1	No. 4	3 5	0 03
1	No. 5	1 0	0 05
1	No. 6	1 5	0 05
1	No. 7	1 0	0 05
1	No. 8	1 0	0 02
1	No. 9	0 5	0 02
1	No. 10	0 7	0 02
2	No. 11		0 10
1	No. 12	0 75	0 05
1	No. 13	2 50	0 05
1	No. 14	0 50	0 05
1	No. 15		
2	No. 16	2 3	0 05
1	No. 17	4 0	0 15
	Hardening	1 2	
	Assemble	2 5	
	Inspect	2 0	
		41.45 hr.	$1 03

[1] Pattern, 8 hr.

C and *D*, respectively. The holes drilled are shown by *X*'s. The two special bushings guide the drills to depressed surfaces.

The piece to be drilled contains three sets of holes, so that the templet is simply moved over to the next pair of holes after the first 12 holes are drilled, as marked in Fig. 29. Details of the templet are shown in Fig. 30. The drill bushings are also marked *X* in this figure.

The pattern work for this templet is given as 6 hr., while the time allowed and the material costs are shown in Table 6.

A pilot boring fixture is shown in Fig. 31. The work is centered from its outside surfaces, being held firmly in position by clamp 13 and screw 21. Clamps 8 and 17 hold the work rigidly down against the fixture seat. Clamp 13 has a free rocking bear-

TABLE 5.—COST OF FIXTURE. (FIG. 28.)

Required	Part	Time allowed, hours[1]	Material cost
	Cutoff stock	0.75	
1	No. 1	10.0	$4.00
1	No. 2	1.25	0.03
3	No. 3	4.0	0.20
3	No. 4	0.75	0.03
6	No. 5	.....	0.60
6	No. 6	.....	0.24
	No. 7	1.5	0.03
3	No. 8	.....	1.15
	Hardening	0.75	
	Assemble	1.0	
	Inspect	1.0	
		21.00	$5.28

[1] Pattern, 7 hr.

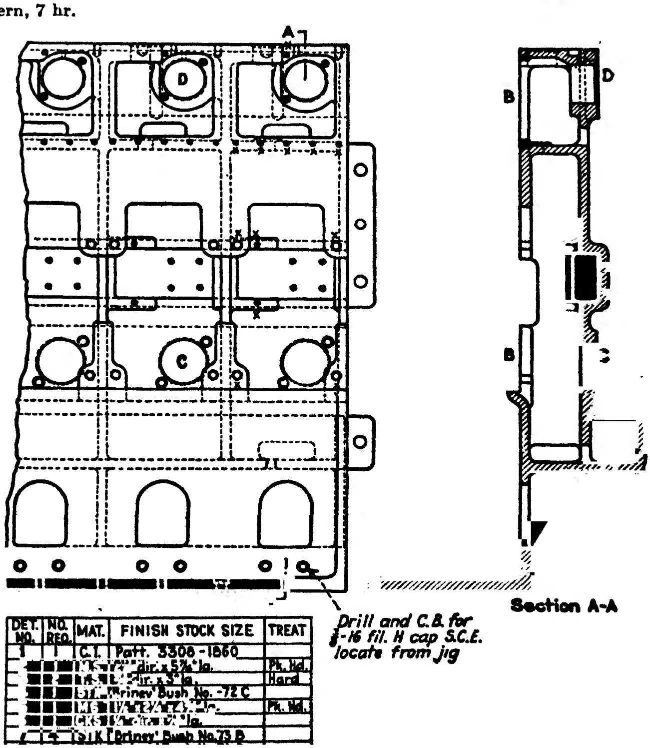


FIG. 29.—Templet fixture with drill bushings.

TABLE 6.—COST OF TEMPLET. (FIG. 29.)

Required	Part	Time allowed, hours[1]	Material cost
	Cutoff material	0.80	
1	No. 1 {Grind. dept. 3 Mill dept. 3 Boring dept. 10}	16.0	$3.60
1	No. 2	8.0	0.50
2	No. 3	4.0	0.25
1	No. 4 tap hole	0.5	0.65
1	No. 5	6.0	0.35
1	No. 6	0.25	0.02
4	No. 7 tap holes	2.0	2.60
5	No. 8 tap holes	2.5	3.75
	Hardening	1.5	
	Assembling	5.0	
	Inspect	2.5	
		49.05	$11.72

[1] Pattern, 6 hr.

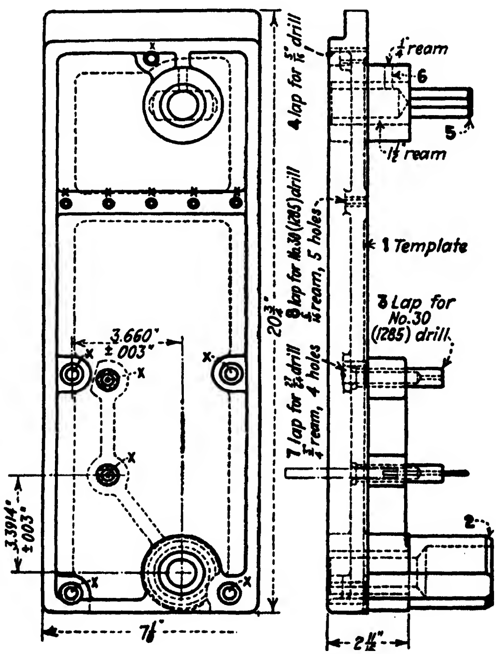


FIG. 30.—A detail of the templet.

ing at its inner end and is operated by the threaded knob 15, which works on the stud 14, the spring 16 opening the clamp when pressure is released. The pilot bushing 12 is of mild steel, pack hardened, and a push fit in the center of the casting.

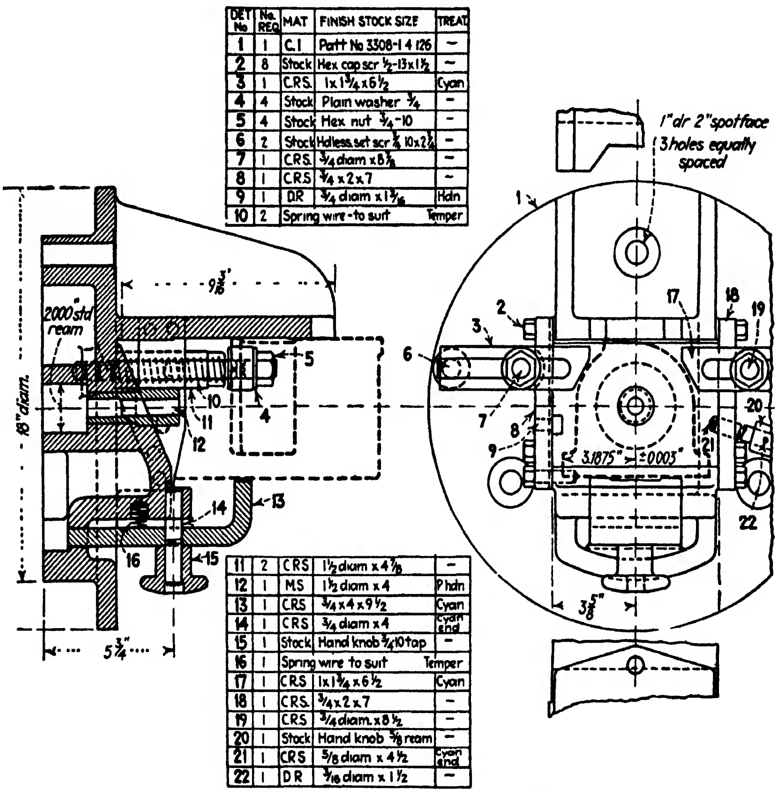
TABLE 7.—COST OF BORING FIXTURE SHOWN IN FIG. 31

Required	Part	Time allowed, hours[1]	Material cost
	Cutoff material	1.75	
1	No. 1 Planing dept.	20.00	$11.20
	No. 1 Scraping dept.	3.50	
	No. 1 Toolroom	20.00	
8	No. 2	.....	0.40
1	No. 3	2.00	0.35
4	No. 4	.....	0.40
4	No. 5	.....	0.40
2	No. 6	.....	0.20
1	No. 7	1.00	0.10
1	No. 8	1.50	0.30
1	No. 9	1.50	0.05
2	No. 10	1.00	0.03
2	No. 11	3.00	0.30
1	No. 12	4.00	0.63
1	No. 13 Forge shop	1.00	0.85
	No. 13 Toolroom	2.50	
1	No. 14	1.50	0.05
1	No. 15	1.50	0.15
1	No. 16	0.50	0.03
1	No. 17	2.00	0.35
1	No. 18	2.50	0.30
1	No. 19	1.00	0.10
1	No. 20	1.50	0.15
1	No. 21	1.50	0.06
1	No. 22	1.50	0.05
	Hardening	2.00	
	Assembling	2.00	
	Inspect	3.00	
		83.25	$16.45

[1] Pattern, 15 hr.

The 22 details of this fixture are shown in the materials list Fig. 31), and the time allowance and cost of each are given in Table 7.

In figuring the final price for a job, the total hours given in the table are multiplied by the current labor rate. This current labor rate, as used by Taft-Peirce, is a single figure, but it includes not only the cost of direct labor but burden and overhead as well. Since these factors are all variables, the multiplier must be



DET No	No. REQ	MAT	FINISH STOCK SIZE	TREAT
1	1	C.I	Patt No 3308-1 4 126	–
2	8	Stock	Hex cap scr ½-13x1½	–
3	1	C.R.S.	1x1¾x6½	Cyan
4	4	Stock	Plain washer ¾	–
5	4	Stock	Hex nut ¾-10	–
6	2	Stock	Hdless set scr ¾ 10x2¼	–
7	1	C.R.S.	¾ diam x 8⅛	–
8	1	C.R.S	¾ x 2 x 7	–
9	1	D.R	¾ diam x 1 3/16	Hdn
10	2	Spring wire - to suit		Temper
11	2	CRS	1½ diam x 4⅛	–
12	1	MS	1½ diam x 4	P hdn
13	1	CRS	¾ x 4 x 9½	Cyan
14	1	CRS	¾ diam x 4	Cyan end
15	1	Stock	Hand knob ¾-10 tap	–
16	1	Spring wire to suit		Temper
17	1	CRS	1x1¾x6½	Cyan
18	1	C.R.S.	¾x2x7	–
19	1	CRS	¾ diam. x 8½	–
20	1	Stock	Hand knob ⅝ ream	–
21	1	CRS	⅝ diam x 4½	Cyan end
22	1	DR	3/16 diam x 1½	–

FIG. 31.—Details of a pilot boring fixture.

changed from time to time to accord with conditions. The cost of materials is added to the figure obtained by multiplying the total time allowance by the hourly rate to arrive at the final cost. It must also be remembered that methods are constantly improving and that these figures may not represent present-day practice. They do, however, form an excellent guide in making estimates.

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